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THE BRITISH JOURNAL OF METALS

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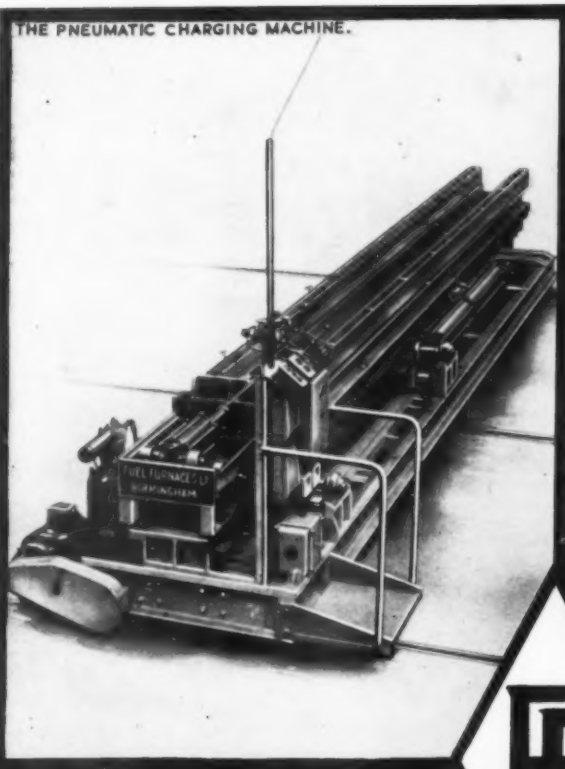

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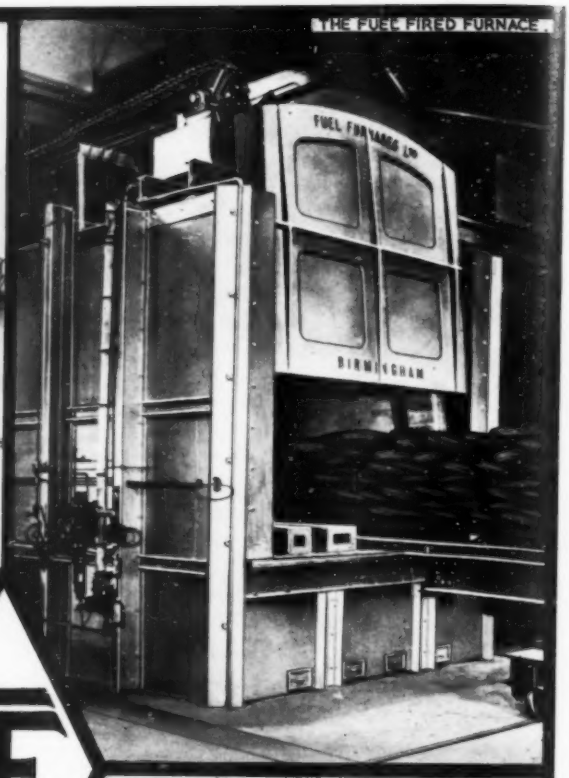

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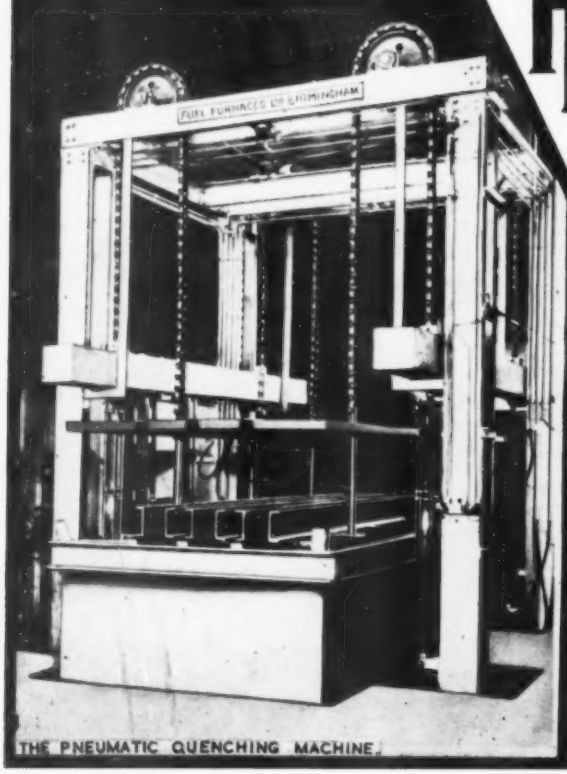

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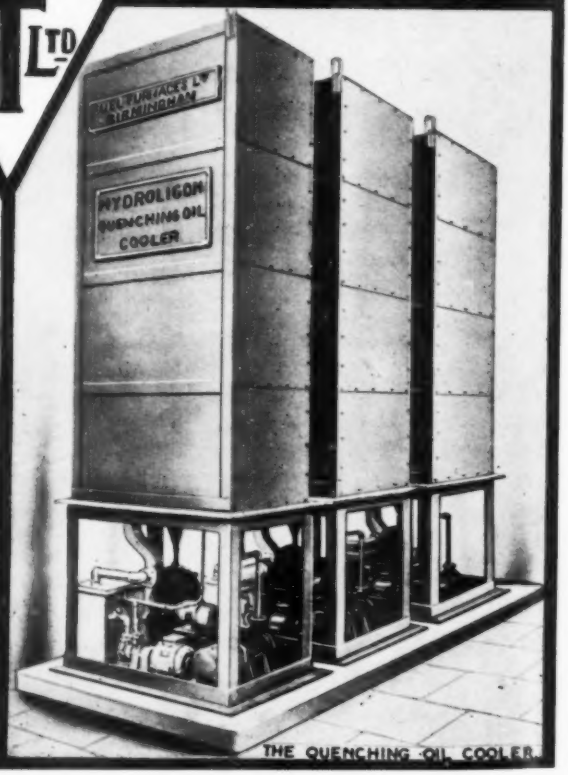

THE QUENCHING OIL COOLER.

METALLURGIA

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INCORPORATING THE METALLURGICAL ENGINEER

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METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

DECEMBER, 1955 Vol. LII. No. 314

Scientific Manpower

VIEWS on the problems arising from the shortage of trained scientists and technologists have been aired in our columns on several occasions, but the problem is one of such importance for the future of the nation that no apology is necessary for returning to it, prompted by the publication of a report by the Committee on Scientific Manpower of the Advisory Council on Scientific Policy. This report deals with the recruitment of scientists and engineers by the engineering industry, and presents the results of an inquiry among leading firms in the industry and four of the nationalised industries.

We take this opportunity of extending to Readers our Cordial Greetings for the Festive Season and Good Wishes for the Coming Year.

As a result of the Barlow Committee recommendations in 1946, the universities have expanded considerably, especially in science and technology. Special steps have also been taken by the present Government to expand higher technological education, particularly in the various branches of engineering. At the university level this is to be achieved by the development of existing universities and colleges in which technology flourishes, rather than by setting up new specialised technological institutions.

These changes have meant some differential expansion of university faculties of science and technology, as compared with the humanities. Even so, this expansion does not, in the view of some authorities, go far enough. To others, however, and especially to some in industry, the expansion appears to have gone too far. In fact, the inquiry referred to above was prompted by reports that some firms viewed with misgiving the expansion of higher technological education and research at the universities, feeling that such changes are at conflict with the real interests of the industry. One of the main worries is that such men as go to the universities to take up engineering are likely to stay too long, and to study and carry out research on matters of little value to industry. Of fifty-four firms answering the question as to whether they preferred to receive graduates (*a*) immediately on graduating; (*b*) after a period of post-graduate instruction; or (*c*) after a period of research, twenty four preferred (*a*), and a further sixteen normally preferred (*a*) but liked a few men with post-graduate or research experience for specialised posts.

One of the main reasons given for this preference is the question of age. It is argued that if a graduate spends an extra two years at the university on work which is generally held to be of doubtful value, and then a further two years on National Service, he will not be ready to enter industry until he is about twenty-five. This is held to be too old for a man to start getting practical experience of industry, and to delay the age at which he should be ready to assume effective command.

Post-graduate courses of instruction, although in some instances not so well supported by industry as the promoters would like, represent a form of post-graduate work in technology which the University Grants Committee feels to be in need of development. With the rapid growth of scientific and technological knowledge there is a case for highly specialised post-graduate courses of instruction, in preference to an increase from three to four years in the length of the first degree course. Such courses would be most likely to benefit men with some industrial experience after graduating, and progress in this field will depend on the co-operation of industrial concerns, or the availability to students taking such courses of maintenance grants, which have hitherto been more readily available for post-graduate research.

Although there is an urgent need for more graduates—the inquiry revealed that many firms managed to engage only three out of every four required—most of the firms co-operating in the inquiry emphasised that quality of graduates was just as important as numbers. Some firms alleged that the graduates of today are inferior to those of the pre-war era, and expressed anxiety lest the continued expansion of the universities should lead to a further fall in the calibre of the students admitted. A good many firms remarked that far too few of the engineering graduates possess real qualities of leadership, stressing that the full benefits of technological training can only be realised if attention is also paid to general education and the development of character.

Another aspect of the expansion which is giving rise to concern is the possibility that it may result in "creaming-off" talent which would otherwise have entered industry directly as apprentices. Not all the firms co-operating in the inquiry take this view, however, and in any case, engineering firms require good graduates as well as good apprentices. The expansion which has already taken place does not, even on the basis of present demand, provide more than about three-quarters of the graduates industry requires, and the demand is likely to increase.

Whilst it may be true that the numbers are available, it is by no means certain that they will wish to enter the engineering industry, for it still appears less attractive than it should to enough boys of intellectual ability and outstanding quality in some of our schools. The future of the engineering industry, on which the whole of industry must be increasingly based, depends on men of strong initiative, and of wide and original interest, coming forward in far greater numbers than they are today. Those who influence the choice of career, particularly parents and teachers, have a special responsibility for seeing that attention is drawn to the fact that engineering and science can be as rewarding, both intellectually and materially, as any other career.

New and Revised British Standards

Light Gauge Copper Tubes for Water, Gas and Sanitation

(B.S. 659 : 1955) Price : 2s. 6d.

This new B.S. 659, a revised edition of that first issued in 1936, and revised in 1944, provides for tubes for the same applications as those covered by the previous edition, namely, tubes for water, gas and sanitation suitable for connection by compression fittings or capillary fittings, or by bronze or autogenous welding.

The 1936 specification standardised the tubes on the basis of the outside diameter—the outside diameter selected for each size being arrived at by adding to the bore dimension twice the wall thickness then in most common use for the particular size. The 1944 revision effected a reduction in the thicknesses of the tubes, the thicknesses in the earlier specification being regarded as more than adequate for the applications for which the tubes are intended. A separate table of dimensions was also included for tubes for sanitation which permitted, for the nominal sizes 2 in. and upwards, thinner wall thicknesses than those specified for water and gas. The outside diameters established in the first issue were retained in both tables in order to avoid disturbance of the existing ranges of fittings for connecting the tubes. A closer tolerance was specified on certain of the outside diameters.

In this revision the method of designating tubes has been retained, but that of expressing tolerances has been clarified, and additional sizes, *viz.*, 5 in. and 6 in. have been included. The value of the tensile strength has been reduced from 17 to 16½ tons/sq. in. Other amendments include the introduction of a weight clause and a new method of marking the tubes.

Methods for the Analysis of Iron and Steel

Part 34 : 1955 Molybdenum in Iron and Steel (Absorptiometric Method)

part 35 : 1955 Aluminium in Iron and Steel and Ferro-Alloys (Mercury Cathode Separation)

B.S. 1121C : 1955 Recommended Method for Mercury Cathode Electrolysis for use in the Analysis of Iron and Steel and Ferro-Alloys

B.S. 1121 : 1955 Price 2s. Each for Parts 34 and 35 ; 2s. 6d. for B.S. 1121C.

The principle of the method described in Part 34 is the preparation of a solution of the sample in sulphuric acid (tungsten, if present, being held in solution with citrate), and the formation of molybdenum and ferric thiocyanates by the addition of ammonium thiocyanate, which are subsequently reduced with a stannous chloride solution in the presence of titanium as a catalyst—the percentage of molybdenum being derived from the measurement of the absorption of the solution.

The principle of the method described in Part 35 is precipitation of aluminium hydroxide from the solution obtained from mercury cathode electrolysis of the sample ; re-solution of the precipitate and removal of iron, titanium, etc. by means of cupferron precipitation and fixing the remaining impurities with potassium cyanide ; and, finally, precipitating the aluminium as a quinolate complex which is evaluated bromometrically.

B.S. 1121C sets out a recommended procedure for mercury cathode electrolysis. It may be employed for the removal of iron, chromium, nickel, copper, cobalt and manganese, the electrolyte subsequently being employed in the determination of such elements as aluminium, titanium, vanadium and zirconium.

Wrought Aluminium for Electrical Purposes : Wire

(B.S. 2627 : 1955) Price 2s. 6d.

This new British Standard has been prepared because of the increasing use of aluminium for electrical conductors of many types. It refers only to wire used for electrical conductors such as overhead transmission lines, insulated cables, or windings for rotating machinery or transformers ; and is suitable for controlling the quality of wire supplied for electrical components made to other British Standards such as B.S. 215, ' Hard-Drawn Aluminium and Steel-Cored Aluminium Conductors', and B.S. E21 ' Electric Cables for Aircraft '.

Wire for general engineering and other purposes, is specified in B.S. 1473 Rivet, Bolt and Screw Stock for Forging, and B.S. 1475 Wire, which form part of a comprehensive series of standards for wrought aluminium and aluminium alloys for general engineering purposes (B.S. 1470–77), which are at present under revision.

The present standard is the first of a similar series of standards for wrought aluminium and aluminium alloys for electrical purposes. The system of nomenclature adopted in this standard is cognate with that employed in the general engineering series.

Flat Bottom Railway Rails

(B.S.11 Pt. 1 : 1955) Price 4s.

Up till now B.S. 11 has included not only the specification of the material but also the nominal dimensions of the British Standard sections. The revision of the full specification started some times ago, but it was found that further investigations of the proposed new rail sections were necessary, and work on the remainder of the specification having been completed, it was decided to issue the specification separately as B.S. 11 : Part 1. The present British Standard rail sections in B.S. 11 : 1936 will be retained for the time being, and by the issue of Amendment No. 4 to that specification will now be known as B.S. 11 : Part 2. The new edition of B.S. 11 : Part 2 will be issued as soon as work on the revision of the sections is completed. The standard specifies quality of material, chemical composition and mechanical properties and includes requirements for lengths and for the condition of the finished rails, etc. It differs from the previous edition in a number of respects, the main changes being the deletion of grades other than the so-called " medium manganese " grade and the inclusion of dimensional tolerances.

Aluminium and Aluminium Alloy Ingots and Castings for General Engineering Purposes

(B.S. 1490 : 1955). Price 10s.

The revision of B.S. 1490, which was first issued in 1949, introduces four new alloys. Alloys L.M.17 and L.M.19, which were included in the original edition, have been omitted. Some of the alloys have been included in conditions not previously covered, and a number of amendments have been made to the chemical compositions and mechanical properties of the other alloys.

Copies of these British Standards are obtainable from the British Standards Institution, Sales Branch, 2, Park Street, London, W.1.

Recrystallization in Metals as a Recovery-Nucleated Process

By A. J. Kennedy, Ph.D., A.M.I.E.E., F.Inst.P.

Head of Metal Physics Section, British Iron and Steel Research Association

Some recent developments in ideas concerning the origin and characteristics of recrystallization nuclei are reviewed. These ideas appear to have much in common, notably in the important part sub-boundaries are considered to play in such processes.

Introduction

ALTHOUGH the processes by which a deformed metal may relieve internal stresses during annealing are numerous, they may be divided broadly into three classes—those of recovery, recrystallization and grain growth. The exact division between recovery and recrystallization is not always agreed, and is somewhat arbitrary, as Thorley[1] has noted. As a working principle we may say that recrystallization involves a detectable structural change, whereas recovery does not. Grain growth is then (in a sense) a special case of recrystallization in which nucleation of new crystals does not occur, the existing crystals simply growing at the expense of neighbours by boundary migration. A great deal of literature exists on these topics, and several reviews have appeared in the last few years which cover fairly exhaustively both the theoretical and the experimental work in the field. Amongst these are the reviews of recrystallization and grain growth by Burke and Turnbull,[2] that of rate-processes by Betcherman,[3] and others on creep and recovery,[4] and polygonization.[5,6] In addition, a most useful survey is incorporated in Cahn's paper on recrystallization theory.[7] Certain special dislocation aspects have been treated by Cottrell[8] and Read.[9] We shall draw freely on these comprehensive reviews in briefly setting out, as an introduction, the main features of the processes.

Recovery processes are essentially those by which some measured property of a material subjected to an initial treatment returns with time towards its original value. The quantity in question may be a fairly direct electrical or mechanical one, such as resistivity or internal stress, or it may be a more complex function of a number of properties, but in general it refers to the softening processes which take place during annealing after prior cold-work. One established mechanism in such a process is that of polygonization, in which the dislocations in a bent lattice redistribute themselves in arrays to produce a number of polygon elements with small angles between the elements of a few minutes of arc.

Recrystallization ideas are based on the concept of a nucleation frequency ($\dot{N}$) and a growth rate (G), each physically distinct processes. The main conclusions of work in the field (Kornfeld,[10] Johnson & Mehl,[11] Anderson & Mehl[12]) may be summarized briefly as follows. $\dot{N}$ appears to be a thermally activated process, and is a function of the annealing time t, commencing at zero, and, after an induction period, rising to a maximum (see Fig. 1) and then decreasing. For light prior deformation, the $\dot{N}$-values are smaller for coarse-grained than for fine-grained material. Heavy deformation produces curves of the same general shape, but the curve is

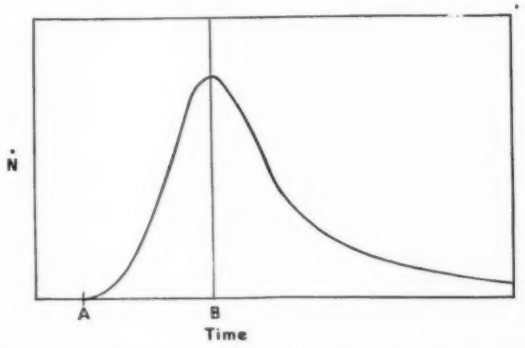

Fig. 1.—The rate of nucleation ($\dot{N}$) plotted against time in isothermal recrystallization.

shifted towards shorter times with higher $\dot{N}$-values. A similar shift occurs if the temperature of the test is raised. Nuclei are formed in regions of high deformation, such as at grain boundaries and in active glide-planes, and single crystals deformed by purely laminar slip will not recrystallize. Pre-annealing at a temperature too low to cause recrystallization increases $\dot{N}$ in single crystals, although with polycrystalline metals the results are conflicting.

Experimental observations such as these led Burgers and Louwerse[13] to suggest that the strongly curved regions were responsible for the formation of nuclei, and subsequently Cahn[7] has been able to reconcile this idea with his polygonization propositions by demonstrating that after a time one of the polygonized domains could grow at the expense of the others. One unsatisfactory aspect of such models is that of the conflicting conditions which have to be imposed on the boundary between the growing nucleus and the matrix. Polygonization-growth involves fairly low-angle boundaries, and decreases in rate as these angles increase, whereas high-angle boundaries appear to be necessary for the high mobility observed in the growth process. Some reconciliation of these requirements appears to be possible.

One manifestation of the recovery process arises in creep under conditions in which the stress is not applied continuously. During primary creep the metal work-hardens and the creep rate diminishes. If the stress is removed for a period a partial recovery occurs, and on reloading the creep rate is greater, for a given total load time, than that for the case of a continuously applied stress. The creep curve exhibits, in fact, a new small transient (see Fig. 2). Intermittent creep of this kind, and its complexities, has received fairly extensive con-

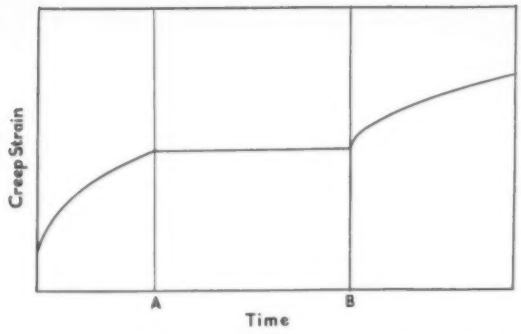

Fig. 2.—The effect of removing the stress, during the period AB, on the subsequent creep behaviour of a metal.

sideration,[14, 15] and is certainly a subject of much contemporary interest. The greater part of the work is, however, irrelevant to the present discussion, and we may limit our consideration strictly to those results which bear directly upon the problems of recovery and recrystallization. The object of this consideration is to demonstrate that a self-consistent view of such phenomena is possible by standard rate-process methods, without the introduction of arbitrary functions or distributions, and that much of the recent work on the subject is in accord with the basic concepts introduced.

Recovery and Recrystallization Processes in Creep

In order to develop the discussion of the relation between recovery and recrystallization, it is necessary to use certain mathematical formulations already put forward.[14] These will be quoted as necessary ; for fuller derivation reference should be made to the original publications.

The primary creep curve of a metal at a constant temperature is typically of the form

$$\epsilon = \beta t^p \qquad (1)$$

where ϵ is strain, t the time under a (constant) stress, with β and p constants. Over a large range of test conditions p has a value near to 1/3 for both metallic and non-metallic materials.[16, 17] The small new transient which occurs after a stress interruption may be fitted empirically[14] by assuming that two components now exist ; a transient of the form $n\beta(t - \tau)^p$ starting from t, the creep time prior to the interruption, and a component $(1 - n)\beta t^p$, n being a fraction. This implies a region n where recovery is complete (total β-flow recovery) and a region $(1 - n)$ where no recovery at all has occurred. This we may accept for the moment as a useful device in handling the results.

The quantity n depends on the values of τ and ρ (the period of the interruption) according to the equation

$$(1 - n)/n = A(\tau/\rho)^p \qquad (2)$$

for a constant stress and temperature, n therefore being a measure of the amount of recovery that occurs. Experiment shows that A does not, in fact, vary very greatly with the test conditions.

Certain consequences of this type of relationship when the stressing occurs repeatedly have been worked out,[14, 15] but calculations of the behaviour of a model of this kind, for the general case of a variable stress, are extremely laborious, if not impossible. For such complex problems an analogue computer has been specially developed.[18]

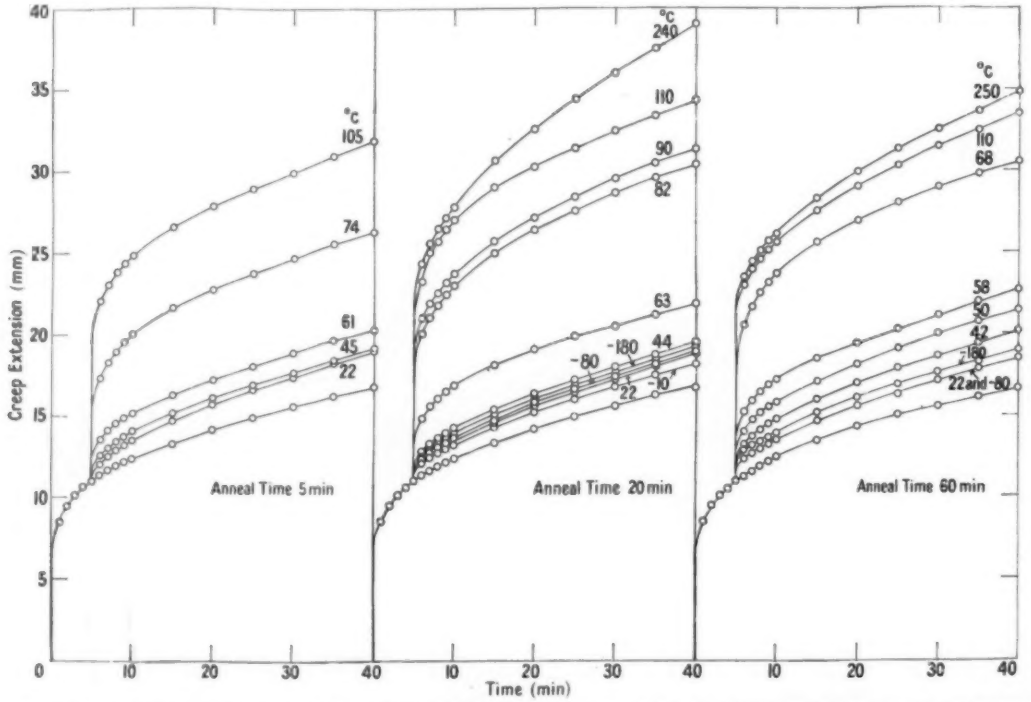

Fig. 3.—Creep curves of pure lead under a stress of 250 kg./sq. cm. at 22° C., interrupted after five minutes creep and annealed for the times shown. The temperature of the anneal is given against the creep curve.

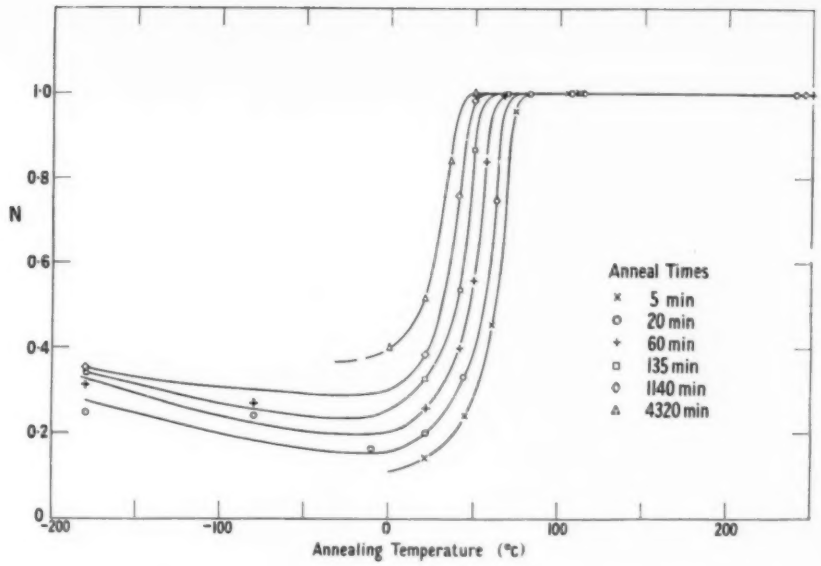

Fig. 4.—The fraction (N) of the metal (for which the full transient flow properties have been restored by the anneal) plotted against annealing temperature for different anneal times.

In introducing recrystallization into the problem, the first point to be settled is the effect of changing the grain size, irrespective of the mechanism by which this is brought about. That such a change does affect the creep properties is well known ; in particular, results on lead[19] show the importance of the ratio of the grain to the specimen diameter. When such materials are tested under intermittent stressing, although the value of the transient creep component (β) changes as the grain size changes (increasing with increasing grain diameter), the fraction n remains the same until the grain diameter becomes commensurate with the specimen diameter. At this point n increases (for any chosen standard conditions). Results on single crystals (the limiting case of large grain size) show that recovery is here very rapid indeed,[20] compared with the polycrystalline case.

We may say, then, that grain size does not affect the recovery properties, at least as far as the recovery of the transient creep is concerned, until the grain size becomes commensurate with the specimen diameter. If tests are carried out, then, on materials which recrystallize during creep, the change in the creep properties brought about by such recrystallization is not due to any grain size change, provided the above grain size limitation applies. Comparative tests have been conducted on a very pure lead, exhibiting recrystallization under the test conditions, and on a less pure lead, which shows recovery only.[21] The procedure was as follows. All the wires of the pure lead examined were first extended in a thermostat under standard conditions of stress and temperature for a fixed time. The stress was then removed, and the wires placed in another constant temperature enclosure, set at the desired " recovery temperature," and annealed for some chosen period. At the end of this period they were retested in the original apparatus at the standard conditions. The type of result obtained is shown in Fig. 3.

In order to interpret such results, the original method of introducing a quantity n to represent the amount of recovery that has occurred must be slightly modified, as recrystallization has also taken place. We therefore denote by the fraction N the extent to which the original transient creep properties have been restored by the combined recovery and recrystallization processes. N is a sum (effectively) of n (recovered fraction) and X (recrystallized fraction), but because of overlapping considerations, n does not have the same meaning as for the case of recovery only. This point we shall deal with later.

This fraction N, deduced from the results presented in Fig. 3, is plotted in Fig. 4 against the recovery temperature for different recovery periods. The most notable general feature of the curves is the very critical increase in N at temperatures of about 50° C. It has been possible to show that the quantity N increases more rapidly with the recovery time (ρ) than predicted by a formula of the form of (2). This increase is certainly due to the operation of the recrystallization process.

In order to handle the problem quantitatively certain assumptions have to be made. In view of the general observations already surveyed in the introduction, one proposes that recovery is a nucleus-creating process. Accepting this, a general theory can be developed in the standard way and the results obtained may then be compared with other quantitative work in the field. The main steps in this treatment of the problem are as follows.

The temperature-dependence of the transient creep process is represented[22] by an equation of the form

$$\epsilon = \psi [t \exp (- H/RT)] \qquad (3)$$

where the ψ-function is a power function, so that for a creep function of the form of equation (1), with p taking the Andrade value $\frac{1}{3}$, we have

$$\epsilon = \beta t^{\frac{1}{3}} \exp (- H/3RT) \qquad (4)$$

H being the activation energy, R the Gas Constant and T the temperature. This provides a value of $H = 18{,}400$ cals/mole for the lead used, compared with values of 19,000 and 23,000 cals/mole obtained by other workers.

In introducing temperature into the recovery process, one notes that similar time functions occur in (2) as in the transient creep equation, $\epsilon = \beta t^{\frac{1}{3}}$. A number of experiments on a variety of metals[23] indicate that, for a given value of p, A does not vary very much with the

test conditions, nor does it vary greatly from metal to metal. It can be shown that this result will arise if the temperature dependence of the recovery is of the same form as (3), and if the activation energies for creep and recovery are approximately the same. The near-equality of these activation energies has been confirmed, at least for some metals.[23] We accept then, that the recovery temperature dependence may be represented by

$$[n/(1-n)]^3 = B\exp(-Q/RT) \qquad (5)$$

where B is a constant, and Q the activation energy for recovery. In this equation, n is the observed recovered fraction, in an interrupted creep test under some selected conditions, with T, the temperature during the recovery period, being the only test variable. If no recrystallization occurs, the fraction recovered at any time is given by, say, $n = f(\rho)$, or

$$dn/d\rho = f'(\rho) \qquad (6)$$

where the function f is, as we know, of the form of (2). The evidence[24] is that recovery is a necessary prelude to recrystallization, and we suppose that this process is a nuclei-creating one. Thus no nuclei are created within any zone, either before or after that zone recovers, but are direct products of the action of recovery. When recovery is complete, no more nuclei are created.

If the number of nuclei formed in the time from α to $\alpha + d\alpha$ is dZ then $dZ = kf'(\alpha)d\alpha$ with k a constant. From these nuclei, recrystallized zones grow, the volume of which, at any instant, is X. The amount of material in which recovery can be effected is reduced, therefore, by recrystallization and (6) becomes

$$dn/d\rho = f'(\rho)(1-X) \qquad (7)$$

where X is the amount of recrystallized material present at the time ρ. The rate of nuclei-creation in the unrecrystallized matrix is therefore

$$dZ = kf'(\alpha)(1-X)d\alpha \qquad (8)$$

If v, the volume of material recrystallized by growth from a single nucleus is related to time t by $v = F(t)$ then the amount of recrystallized material present, after a recovery time ρ, due to nuclei formed at $\rho = \alpha$, is

$$dX = F(\rho-\alpha)kf'(\alpha)(1-X)d\alpha \qquad (9)$$

and the total volume in the period ρ is

$$\int_0^X (1-X)^{-1}dX = \int_0^\rho kF(\rho-\alpha)f'(\alpha)d\alpha \qquad (10)$$

This reduces to

$$\log_e[(1-X)^{-1}] = G\exp(-P/RT)\int_0^\rho [\alpha^4/(c+\alpha^4)]d\alpha$$

by making certain assumptions about grain shape and impingement, and taking the growth rate G as thermally activated, with an activation energy P.

On this basis, we find , for lead, that G is 31,000 cals/mole, which is near to that for the self-diffusion of lead.[25]

Discussion of the Phenomena

The foregoing experimental results on the recovery-recrystallization processes are consistent with the view that the recovery process provides the recrystallization nuclei. The recovery process itself has been shown to follow the same time function as that obtained previously for a tellurium lead which did not recrystallize.

This view of the origin of the recrystallization nuclei is very similar, in principle, to that put forward by Cahn, who considers the nuclei to arise in the highly distorted regions (" local curvatures ") when these polygonize under annealing. The features of such a recrystallization model of this type, and their reconciliation with the published empirical data, have been so comprehensively reviewed by Cahn that it is pointless to retrace the arguments here in any detail.

It is important, however, to note in what respects the above treatment differs from that of Cahn. Whilst this approach considers nuclei to be a product of a recovery process, and indicates that the nuclei may be logically expected to occur at a boundary between recovered and unrecovered material, it does not involve any assumptions regarding distributions of incubation times, or of degrees of local hardening. The number of nuclei active at any instant is assumed to be simply proportional to the amount of material which has achieved recovery (whatever the physical process of that recovery may be). It may be argued that the distribution problems have been simply embodied within an empirical recovery-time relation, and this is true, but it is significant that no complex functions occur in this relation, the time-function being similar to that for the forward creep curve. Thus, while there is no basic conflict with Cahn's proposition, it does appear as if the two mechanisms of creep (or hardening) and recovery (or softening) should be capable of a fairly simple theoretical reconciliation.

It is likely that polygonization is not the only process by which recovery can occur, although a clear experimental demonstration of this has not yet been achieved. For instance, the conclusion has been drawn that experiments on recovery after pure shear (such as those of Kochendorfer)[26] restrict the recovery to a non-polygonizing process, yet the more recent considerations of dislocation theory, in particular those of Mott,[27] make it clear how polygonization can occur under pure shear by the piling up of dislocations, and by their movement out of the slip plane.

The present work does not, and cannot, distinguish any particular recovery mechanism (such as polygonization) as being the one responsible for the creation of nuclei. If it is accepted that several mechanisms are operative, and that polygonization is alone responsible for the nuclei, then it follows from the present work that the fraction polygonized bears a fairly constant ratio to the fraction recovered (by all processes) throughout the anneal.

In the following discussion, no attempt will be made to resolve this particular problem of the part played by polygonization in the general recovery process. The experimental facts of polygonization will be simply accepted and related to certain features of the combined recovery-recrystallization phenomenon. For instance, it is clear that the smaller the strain to which the metal is subjected, prior to annealing, the less will be the lattice curvature, and the smaller the number of polygonized blocks after recovery. Higher strains will result in an increase in the number of these blocks. If the nuclei are created at the discontinuities afforded by block boundaries, then the number of such nuclei (or the constant in equation 8) will be proportional to the number of polygonized blocks, and therefore proportional to the amount of lattice curvature. The grain size, which is inversely proportional to the number of nuclei, will therefore increase as the pre-strain is diminished, and will be greatest for the minimum pre-strain necessary for recovery and recrystallization to occur. This agrees with the general experimental evidence (e.g., Eastwood, Bousu and Eddy).[28] A neat demonstration of the effect has been obtained by annealing tin sheets subjected to bullet impact : the results are reproduced by Doan and Mahla.[29]

The question of the dependence of the final grain size on the annealing temperature is less readily resolved. Previous work on α-brass (Eastwood, Bousu and Eddy),[28] aluminium (Anderson and Mehl),[12] and rock-salt (Möller),[30] has shown that for these materials the activation energy for nucleation (corresponding to the quantity Q in this paper) is very nearly the same as the activation energy for growth (P), so that temperature has little effect on the final grain size. Certain deviations from this have been observed, notably at small prior strains, and in these cases Q was somewhat greater than P, so that the grain size increased with the annealing temperature.

If the problem of final grain size can be treated as simply as this, and the process of true grain growth (that is the growth of certain of the new grains at the expense of neighbours) ignored, then the results for lead[21] suggest that the final grain size achieved by primary recrystallization will diminish with increasing temperature because Q (recovery) is less than P; actually in the case of lead $Q \simeq 2P/3$. There is not yet sufficient evidence to hand to verify this prediction. In any case, it is possible that P falls off at higher temperatures, as it does in copper (Karnop and Sachs)[31] and aluminium (comparing Kornfeld and Pavlov,[10] with Anderson and Mehl[12]). If this were generally true, then clearly the final grain size would be larger than that predicted using a constant value of P. The occurrence of the coarse polygonization observed by Cahn[5] and by Guinier and Tennevin[6] at very high temperatures should also lead to an increased grain size if the postulated relation between the number of nuclei and the number of polygonized blocks is a valid one.

The effect of subjecting the metal to recovery anneals prior to the recrystallization test is a question on which there is no general agreement. For instance, Collins and Mathewson[32] observed that the rate of nucleation in aluminium single crystals decreased with prior annealing, whereas Kornfeld and Schamarin,[10] working with aluminium crystals of commercial purity, observed that it increased, resulting in a smaller final grain size. If indeed it is the recovery process which provides the nuclei for recrystallization, then clearly a prior anneal must provide a larger number of nuclei at the outset and thus the grain size must be smaller. The theory therefore supports the observations of Kornfeld and Schamarin.

As far as the growth rate is concerned, this should remain unaffected by the prior anneal (ignoring impingement considerations), a result in general agreement with experiment (e.g., Müller,[30] Kornfeld and Pavlov[10]). Another consequence of the theory is that prior annealing should lead to a more uniform grain size; no reliable experimental evidence on this point appears to be available.

In reconciling the general feature of the observations in this way, we are left with the fundamental problem of the mechanics of the actual nucleation process. A recent publication[33] suggests that this may be considered as a process of "geometrical coalescence" of neighbouring grains. It is shown that if by chance two neighbouring grains are close in their relative orientations, so that the common boundary has a low specific free energy (σ), then the grain boundary arrangement is very unstable, particularly if the connected boundaries have high σ values. These form a complex grain of two subgrains which grows at the expense of its neighbours. The geometrical analysis of the growth process need not be reproduced here. Although certain difficulties remain, much can be explained on this basis, and it is significant in that the geometrical arguments are applied to a model which has much in common with that of polygonization theory. The induction period is explained on the "geometrical coalescence" basis as being the period prior to the meeting of two grains destined to coalesce geometrically. This appears to be a somewhat awkward interpretation of the incubation phenomena, and one which does not arise if incubation is considered as the (recovery) process during which the polygon boundaries are formed. Thus, although opinions differ in detail as to the nature of the recrystallization process, it is evident that recent trends of thought on the subject have much in common, notably in the part played by the formation of sub-boundaries.

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New H.B. Sheffield Office

To meet the increasing demand for industrial instrumentation and automatic controls for space heating, ventilation and air-conditioning, the Sheffield Office of Honeywell-Brown, Ltd., has now moved from Oak Dale Road to larger premises at 119, Petre Street, Sheffield, 4. Under the management of Mr. W. R. Owen, the new office will provide improved sales and service facilities in the Sheffield area.

Change of Address

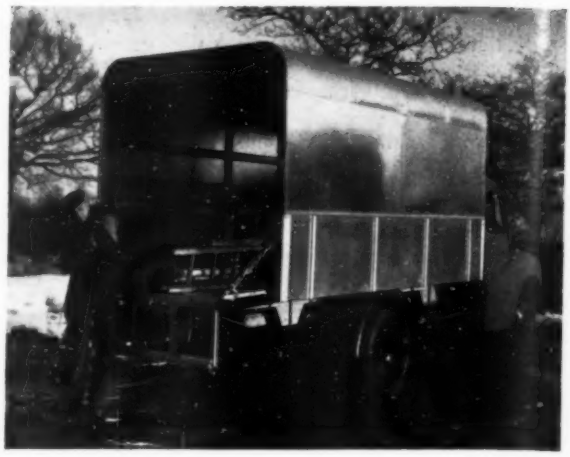
The Belark Tool & Stamping Co., Ltd., makers of the Belark aluminium soldering tool, have recently moved to 9, Carnaby Street, London, W.1. (Tel.: GERrard 2178).

Light Alloy General Purpose Lorry Body

VERSATILITY is the keynote of the new light-weight general-purpose lorry body which has been developed by the Transport Department of the Midlands Electricity Board, in conjunction with Northern Aluminium Co. Ltd. Fabricated entirely in aluminium plate, sheet, and extruded section, this latest addition to the M.E.B.'s large road transport fleet combines many features which facilitate its use for all types of general-purpose work.

Mounted on an Austin 2/3 ton chassis and weighing approximately 9 cwt., the new body affords a weight economy of 7 cwt. over the similar timber bodies at present in use, and therefore allows a heavier load without overloading the chassis or the engine. Another big advantage is that, even with the installation of a diesel engine which weighs approximately 3 cwt. extra, there is still a saving of 4 cwt.

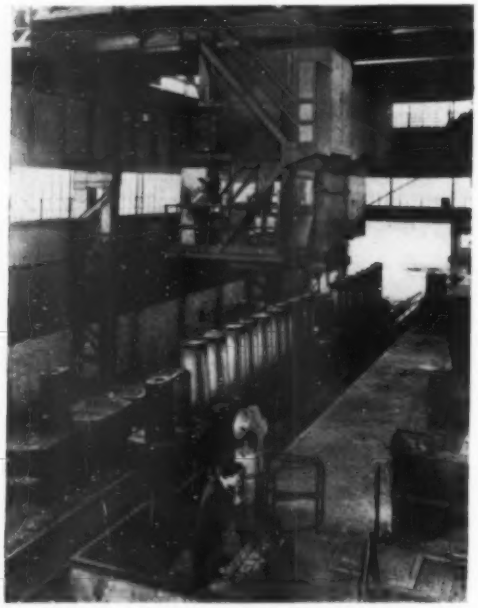
The strong, yet light, underframe has crossbearers and main longitudinal members of extruded Noral 51SWP channel section, with riveted brackets for additional strength. The flooring, the 20 in. high sides, front end and tailboard are of Noral 65SWP plate, riveted to a framework of extruded "top hat" section in Noral 51SWP. Two men can remove the demountable "lift-off" canopy (Noral 57S½H sheet riveted to a formed framework of top hat section) in a few minutes. The canopy can also be used for workmen's protection during inclement weather; it will not require the numerous re-coverings necessary with the canvas tarpaulin type and it reduces the weight considerably.



An interesting feature of the vehicle is the double tail-board, which allows for the storage of ladders under the seats on the off-side. The seats are also used as tool lockers, and there is adequate stowage space for gear. A gantry and hinged flap at the front end facilitates the carriage of poles.

Communications in Steel Works

FOUR more important orders for Clearcall equipment—all for steel works—have been obtained by the British Thomson-Houston Company. The first, a repeat order, comes from The Steel Company of Wales, Ltd., and is for carrier-frequency equipment for providing communication between personnel at four ore transporters, hatchways, stockyards, and foreman's office, the last mentioned being the operational point for the whole plant. Several frequencies will be used so that a number of conversations can take place at the same time. Another interesting feature is that this is the first installation where the carrier-frequency signal is injected into or imposed on a 3·3-kV power supply. The same company has also placed a second order with B.T.H., in this instance the equipment being for two-way communication between the ground and overhead cranes.



Clearcall ground-to-crane equipment at Consett.

The third order comes from the International Construction Company—consulting engineers for Guest Keen Iron & Steel Co., Ltd.,—who have asked for equipment to be put in hand immediately for providing communication in a large ore handling plant being built at Cardiff. Here again Clearcall carrier-frequency equipment will be used, The system will, however, include a new feature known as "selective calling", by means of which the operator at the control point can call up and speak to a pre-selected outstation without being overheard at other stations—although all equipment operates on the same carrier frequency. This is achieved by transmitting to all stations a tuned note on the carrier, each station having its own calling note relay which closes when it receives that note and connects the speaker to the receiver.

The fourth order—another repeat—is from John Lysaght's Scunthorpe Works, Ltd., and is for Clearcall equipment for two-way communication between ground points and soaking pit cranes.

Ferrous Materials in Marine Engineering*

The Twenty-Fourth Andrew Laing Lecture

By S. F. Dorey, C.B.E., D.Sc., F.R.S.

Chief Engineer, Lloyd's Register of Shipping

In this Lecture, delivered before the members of the North East Coast Institution of Engineers and Shipbuilders in Newcastle upon Tyne recently, Dr. Dorey said that plain carbon steels continue to predominate other structural materials in the marine field, but, during the twenty-five years since Andrew Laing's death, new fabrication and treatment processes and many alloy steels have been employed to simplify production and overcome adverse service conditions. More recently, special high-duty cast irons have also assisted in these respects.

WHEN Andrew Laing commenced his career in marine engineering in 1877, mild steels, particularly of the open-hearth type, were regarded as a novelty, and were termed "new materials." The number of steel ships in service was comparatively small, and wrought- and cast-steel machinery and boiler components had generally been made of expensive crucible types. However, prejudice against steel construction had been largely dispelled and during the next few years the consumption of high-quality mild steels rose sharply. The life of a wrought-iron crankshaft averaged from three to three and a half years, but steel shafts made by piling bars which were forged and rolled proved little better than the "faggoted" iron shafts. This situation gave impetus to the development of techniques for the casting of large good-quality mild-steel ingots, and to the construction and installation of presses capable of handling these ingots at the forge. Improvements in the quality of the larger ingots enabled intermediate and screwshafts to be forged of sizes greatly in excess of the limit of about 18 in. diameter imposed in wrought-iron practice.

While the performance of steel crankshafts and intermediate shafts improved markedly, failures of steel screwshafts attained proportions which gave rise to great concern. Sterner measures taken to exclude contact of the shaft with sea water did not produce the desired results. A forged alloy-steel shaft was put to the test in 1899 and it proved no better than the mild-steel shaft it replaced. To reduce the screwshaft failures at sea, a biennial examination was imposed by the classification society, and a 5% increase in the rule diameter made. Thus, alloy steels had an unfortunate introduction in marine engineering, and the "expensive" experiment was probably responsible for the future policy of favouring plain carbon types.

With the increased output of marine machinery, iron-founders were called upon to produce large quantities of castings for low-stressed components, and the properties of the castings then produced were adequate to meet the service conditions; it was not until the 1914–18 war period, when cast irons of higher strength were required for armament purposes, that scrap steel was accepted as a proportion of the cupola charge. Oil-engine development has largely been responsible for the increasing use of high-duty and alloyed cast irons in marine applications.

After briefly reviewing the early uses of iron and steel in marine engineering, Dr. Dorey directed attention to some of the more recent trends, particularly with regard to shafting, reduction gearing, pistons, turbine blading, stationary turbine parts, steam plant, and propellers, some of the main features from which are given in the following notes.

Shafting

With some exceptions, plain carbon steels are used for the manufacture of thrust, gear, intermediate and screw-shafts. Of the medium carbon steels available, those of the lower carbon content, 0·22–0·27%, predominate in merchant-ship practice. Thus, the normalised forgings have a tensile strength within the range of 28–32 tons/sq. in., but with the trend to compact reduction gearing there has been an increasing use of "40" carbon steels for the large gear-shafts, the 35–40 tons/sq. in. tensile strength permitting reduced scantlings.

Shaft forgings are solid, except in naval practice where hollow bored "30" carbon steel forgings are used. For many years the U.S. Navy has preferred alloy steels for the shafting of large ships; either one containing more than 2¾% nickel or one containing 0·5% molybdenum and 0·2% vanadium, the mechanical properties of these steels being similar. Table I gives details of alloys specified for shaft forgings in the annealed or normalised and tempered conditions.

The corrosion-fatigue strength of low-alloy steels is not greatly in excess of that of mild steel. So far as the loss of a propeller at sea, due to the fracture of the screwshaft, is concerned, the rate of propagation of a fatigue crack may be of greater importance. The slow rate of crack propagation experienced with mild steels increases the chances of detection at normal survey periods, particularly if magnetic crack-detection is employed. Although the stress level may have some influence, some consider that fatigue cracks propagate more rapidly in high-strength alloy-steels than in the lower-strength plain carbon steels, but this has not been effectively demonstrated. Despite the attention which was drawn in earlier days to screwshaft casualties of single screw merchant ships, these components still represent a source of weakness. It is noteworthy that the Engineering Research Department of Lloyd's Register of Shipping is at present undertaking, on behalf of B.S.R.A., fatigue tests of screwshaft assemblies, from which a satisfactory solution may result.

In contrast to steel screwshafts fitted with gunmetal liners, those which operate in oil-lubricated sterntube

* An abridged version of the Twenty-Fourth Andrew Laing Lecture which will be published in full in the Transactions of the North East Coast Institution of Engineers and Shipbuilders.

TABLE I.—WROUGHT STEELS FOR SCREWSHAFTS.

No.	Type	Steel Composition						
		C%	Mn%	Si%	Ni%	Cr%	Mo%	V%
Aa	C Steel	0·22	0·67	0·20	0·12	0·10	—	—
Bc	Alloy An.	0·45 max.	—	—	2·75 min.	—	—	—
Cc	Alloy An.	0·45 max.	0·5/0·9	0·15/0·45	—	—	0·3/0·6	0·1/0·25
Dc	Alloy No. 4	0·45 max.	1·0 max.	—	3·75 max.	2 max.	1·0 max.	0·1 min.
Ea	13% Cr Steel	0·15	1·20	0·80	—	13	—	—
Fa	18/8 Steel	0·10	0·80	0·80	8·5	18	Ti–0·6	—

S and P less than 0·050% each in all cases.

TABLE I. *(cont.)*

Type	Condition	Mechanical Properties (Longitudinal)			
		Yield Stress (tons/sq. in.)	Ultimate Tensile Stress (tons/ sq. in.)	Elongation (% on 2 in.)	R. of A. (%)
Aa	A.C. or F.C.	19	30	32	55
B & Cb	A.C. or F.C.	20	36	25	45
Db	A.C. or F.C.	45	53	15	40
Eb	A.C.	—	38	30	40
Fb	A.C.	18	40	35	50

a = typical values. *b* = minimum specified values. *c* = U.S. Military Specification. MIL.-S-890 (Ship) 15.8.49

bearings suffer the greater proportion condemned due to excessive corrosion at the aft end. As the shafts are usually replaced before the corrosion is sufficient to cause complete failure, there has been a tendency for the importance of the number involved annually to be overlooked. In consequence, few measures were taken to protect the shaft from corrosive attack, although nowadays the importance is appreciated.

Neither martensitic nor austenitic stainless steels have been widely used for screwshafts or liners. In the bearing application, the limited experience indicates that stainless steels do not rival gunmetal and are more prone to grooving by abrasion, and to pitting. Economics and to some extent ingot size, limit the sections of stainless-steel screw shafts to about 10 in. diameter. Table I gives details of a martensitic and an austenitic stainless steel both of which have been used for screwshafts. The few in service have so far proved satisfactory, but either a 13% chromium, 1% nickel, employed for the tailstock and other parts of ships' stabilisers, or an S.80 alloy steel, is to be preferred to the "straight" chromium steel quoted for service in seawater.

Appreciable reduction in the stiffness of parts of the intermediate shafting can be derived from the reduction in shaft diameter obtained by employing a high-strength, heat-treated, low-alloy steel in place of mild steel. This could be of value when it is desirable to lower the one node torsional natural frequency of a main shafting installation. For similar working stresses the section and the rigidity of the alloy-steel component will be lower unless the section design is altered. Rigidity frequently controls the design of machinery components.

A number of proposals have been made for the entire construction of semi-built crankshafts from cast steel components, but these have not materialised, largely due to difficulties in production and consequent cost; however, large single webs, weighing up to 3¼ tons, and single throws are cast in "20" carbon steels. These are usually annealed and tempered to reduce casting stresses. During the last eight years, Italian practice has favoured a low-alloy steel with a typical analysis of: 0·16% carbon, 0·3% silicon, 0·65% manganese, 0·5% nickel, 0·2% chromium, and 0·15% vanadium. The castings are annealed, normalised and tempered to a tensile strength of 32–38 tons/sq. in.

The increased use of high-duty cast irons for the crankshafts of marine reciprocating engines and pumps was largely due to the encouragement American manufacturers received from the U.S. Navy. The main types of materials used for these purposes include: chromium-copper-silicon cast iron, copper-molybdenum cast iron, low molybdenum cast iron, Meehanite GA and GM, and nickel-molybdenum cast irons of varying compositions. The irons included in the last two groups have been most widely used for marine crankshafts. With the nickel-molybdenum irons, the proportion of these elements employed depends on the sectional size of the castings, the aim being to obtain an acicular structure. One firm, which has cast a large number of oil-engine crankshafts, quoted an average analysis of: 2·65% carbon, 1·4% manganese, 1·95% silicon, 1·0% molybdenum, 2·1% nickel, 0·03% sulphur and phosphorus. The heat treatment given to cast-iron crankshafts amounts to little more than a light temper at about 350° C., relieving casting stresses and slightly improving machinability and mechanical properties.

During recent years considerable progress has been made in the use of spheroidal graphite irons for cast crankshafts. Of the two methods employed to make the best use of these irons, i.e., full annealing to obtain maximum ductility with the ferrite and spheroidal graphite structure, or heat treating to give high strength and only measurable ductility with the sorbitic matrix, the latter has been preferred for crankshaft castings for oil engines. This arises from the superior wear resistance of the latter structure, as well as the greatly improved mechanical strength. Accurate control at all stages of manufacture from melt to the completion of casting is regarded as essential if reliability of product is to be achieved. While the aim of foundries casting crankshafts in spheroidal graphite iron is to produce large components, present production concerns small shafts of 6 in. diameter and less, but a trend to the larger crankshaft is inevitable. These cast crankshafts are heat treated by either normalising or oil hardening and tempering, according to practice. The mechanical properties of the actual castings would have the following minimum values: yield stress 25 tons/sq. in., ultimate tensile strength 38 tons/sq. in., and elongation on 2 in. 1%.

Forged crankshafts which have a finished diameter in excess of 10 in. are, almost without exception, made of medium carbon steels meeting the requirements of B.S. En.4 for the normalised condition. Where higher tensile strengths and yield ratios are required, the forgings are invariably oil quenched and tempered. The selection of

the steel concerned naturally depends on the section size and the required mechanical properties; those widely used in marine practice for 40 tons/sq. in. maximum tensile strength, in sections up to 9 in., are to En.8. Where increased toughness and a 60% specified yield ratio are required, a 1·2% manganese steel (En.14 or 15) or a 1% nickel steel (En.12) or a 1% chromium steel (En.18) is used, the first two quoted being preferred. In addition, a 0·55% carbon steel to En.9 has also been employed for small crankshafts, but to a lesser extent than the former steels. In higher-speed engines, where shafts complying with a 50 tons/sq. in. minimum tensile strength and a 75% yield ratio are required, 1% chromium-0·2% molybdenum steels (En.19, 34Cr Mo4) are used in sections up to 6 in. diameter. For auxiliary engines with shafts of 4 in. diameter, the Germans employ a 1% silicon, 1% manganese steel (37 Mn, Si 5) the surfaces of the pins and journals being flame or induction hardened. For these and higher strength requirements, other practices favour the nickel-chromium-molybdenum steels to En. 24, 25, and 26, the last stated giving tensile strengths in excess of 60 tons/sq. in. with a 75% yield ratio for 5 in. diameter shafts. The 3% chromium-molybdenum, 3% chromium-molybdenum-vanadium (En.40) and 1·5% chromium-aluminium-molybdenum (En.41) steels are mainly found in small high-strength shafts having nitrided surfaces. Typical analyses and properties of the above steels are given in Table II.

TABLE II.—TYPICAL PROPERTIES OF SOME WROUGHT STEEL CRANKSHAFTS.

No.	Type	Actual Analysis C%	Si%	Mn%	Ni%	Cr%	Mo%
1	EN8	0·38	0·22	0·75	0·20	—	—
2	EN8	0·40	0·26	0·85	—	—	—
3	EN12	0·36	0·27	1·35	0·60	—	—
4	EN12	0·38	0·27	0·85	1·10	—	—
5	EN15	0·35	0·27	1·25	—	—	—
6	EN19	0·35	0·25	0·60	—	1·25	0·40
7	EN25	0·29	0·27	0·60	2·55	0·65	0·55
8	EN40	0·25	0·20	0·55	0·30	3·00	0·50

S and P less than 0·050% each in all cases.

TABLE II (*cont.*)

No.	Section	Heat Treatment	Actual Longitudinal Properties: Yield Stress (tons/sq. in.)	Ultimate Tensile Stress (tons/sq. in.)	Elongation (% on 2 in.)	R. of A. (%)	Average Izod (ft. lb.)
1	9 in.	A.C.860°C.	22	38	26	45	—
2	9 in.	A.C.880°C.	24	41	25	42	—
3	6 in.	O.H.830°C.T.650°C.	30	43	27	60	—
4	6 in.	O.H.850°C.T.600°C.	33	46	28	60	75
5	9 in.	A.C.850°C.	28	42	25	50	—
6	4½ in.	O.H.850°C. T 660°C.	46	55	22	60	50
7	4½ in.	O.H.850°C.T.650°C.	57	65	20	60	60
8	3½ in.	O.H.900°C.T 600°C. Nitrided	55	62	20	60	60

TABLE IIa.—ADDITIONAL WROUGHT CRANKSHAFT STEELS.

No.	Composition C%	Mn%	Si%	Cr%	Ni%	B%	P%
1	0·43/0·50	0·75/1·0	0·2/0·35	0·2/0·35	—	—	0·04 max.
2	0·45/0·50	0·75/1·0	0·2/0·35	0·2/0·35	—	0·0005 min.	0·04 max.
3	0·15 max.	1·0 max.	1·0 max.	16/18	9·5/12	—	0·2/0·4

0·03/0·08V.% as alternative to B.

TABLE IIa (*cont.*)

No.	Minimum Mechanical Properties: Yield Stress (tons/sq. in.)	Ultimate Tensile Stress (tons/sq. in.)	Elongation (%on 2 in.)	R. of A. (%)	Hardness (Brinell)
1	31	49	18	40	229*a*
2	28	45	20	45	201
3	36	53	18	30	241

a = induction hardened to Rc 50–55.

Rotor Shafts

The majority of rotor shafts for marine steam turbines operate at temperatures below 800° F. As creep does not present a serious problem under these conditions, medium carbon steels are used for the shafts of both solid and built up rotors. Carbon contents range from about 0·18% to 0·45%, which, in the normalised and tempered condition, give tensile strengths between 28 and 42 tons/sq. in. The guaranteed yield stress also increases with carbon contents and tensile strengths, and some manufacturers prefer those of the higher values for shafts on which discs are shrunk. Where shafts are of welded construction, however, the carbon content is usually below 0·25%. In post-war years in Italy, a 0·2% carbon, 1·2% manganese, 0·15% vanadium steel has been introduced for forgings for welded rotors. These forgings are heat treated by normalising from 900 °C, oil quenching from 860° C and tempering at 660° C. for a tensile strength of 34–38 tons/sq. in.

Higher strength steels, which provide more uniform properties throughout the mass of the rotor, comprise 1% (or higher) nickel steels, 3% chromium-molybdenum steels, and 2½% nickel-chromium-molybdenum steels. Forgings of these steels are either normalised and tempered or oil hardened and tempered, although the former treatment is preferred by manufacturers. Similar steels in conjunction with 3% nickel and 3% nickel-chromium-molybdenum steels are invariably used to make turbine discs, but in these instances the latter treatment is applied.

When steam temperatures exceed 800–850° F., the superior creep-resisting carbon-molybdenum steel usually replaces the carbon and nickel steels. In the few British installations operating at 950° F., carbon-molybdenum steels have been used for the rotors. Above this temperature, and up to about 1,050° F., the trend is to employ molybdenum-vanadium steels. The hardenability of these alloys is relatively poor, and close control of composition and heat treatment is necessary to obtain good creep properties.

The use of higher steam temperatures for land and marine steam turbine plants has called for increased stability of rotors. Stress-relieving treatments are being applied to reduce residual stresses induced in the forging by either temperature gradients and transformations during cooling from the initial heat treatment temperature, or cold work as a result of machining. The aim is to reduce these stresses to a level which is unlikely to result in further permanent distortion during service. Thermal-stability tests are effected either by the forgemasters or turbine builders on forgings which have completed the normal heat treatment.

The inlet temperatures of gas turbines which operate in conjunction with free-piston gas generators are below 850° F. In consequence, no special materials are required for the rotor forgings other than the carbon-molybdenum and chromium-molybdenum steels previously considered. Of the conventional long-life types of gas turbine, few have been in service at sea. Several axial and circumferential cracks were discovered in the high pressure rotor of one of these units, indicating that careful design and control in operation are essential in

TABLE III.—STEELS FOR TURBINE ROTORS.

No.	Composition						
	C%	Si%	Mn%	Ni%	Cr%	Mo%	Others%
1	0·35	0·20	0·68	—	—	—	—
2	0·40	0·20	0·70	—	—	—	—
3	0·30	0·25	0·85	0·30	—	0·60	—
4	0·32	0·20	1·10	—	1·0	0·20	—
5	0·30	0·26	0·65	—	3·5	0·55	—
6	0·38	0·25	0·75	1·10	—	—	—
7	0·33	0·25	0·70	2·25	—	—	V—0·1
8	0·20	0·28	0·60	0·40	0·40	0·70	V—0·25
9	0·09	0·65	1·50	11·0	18·0	—	Ti—0·1 Nb—1·15
10	0·24	0·70	3·0	18·2	15·7	2·6	Co—6·9, Ti—·16, Nb—1·7.

Steel 9 = FCB(T); Steel 10 = REX 326F, for gas turbines.
Steels 7 and 4 are typical of American practice for service with steam temperatures of 950° F. max. and 1,050° F., respectively.

TABLE III (*cont.*)

No.	Condition	Mechanical Properties (Longitudinal)			
		Yield Stress (tons/sq. in.)	Ultimate Tensile Stress (tons/sq. in.)	Elongation (% on 2 in.)	R. of A. (%)
1	A.C. 880° C.	18	35	31	47
2	A.C. 870° C., T.690° C.	21	38	29	42
3	A.C. 890° C., T.690° C.	32	43	26	52
5	A.C. 920° C., T.640° C.	41	55	26	64
6	A.C. 870° C., T.620° C.	22	42	25	45
8	O.H.970° C., T.690° C.	45	51	24	65
9	—	14*a*	37	52	60
10	—	25*a*	42	26	28

a = 0·1% proof stress.

order that thermal stresses may be minimised, particularly in solid rotor forgings. The cracks were both deep and extensive and occurred in about 600 hours operation at a designed inlet temperature of 1,250° F. The rotor body was of an austenitic 15–13–3 tungsten alloy having axial blade slots. This case was exceptional, however, for rotors of most British and Continental gas turbines have given little trouble.

The manufacture of austenitic steel disc and rotor forgings present many problems, and the degree of uncertainty in quality has influenced some aircraft designers to adopt creep-resisting ferritic steels operating with improved cooling. The trend is also evident in some marine gas turbines with maximum inlet temperatures of 1,340–1,400° F., when discs of H 46 or REX 448 being mounted on shafts of heat-treated low-alloy steel. The manufacture of discs in these materials presents few difficulties, and proving by non-destructive testing methods is simpler and far more reliable than for austenitic alloys. On the other hand, the creep properties of the austenitic types are more attractive and the forging and proving techniques can be simplified if the rotor comprises a welded assembly of a number of forgings. Both FCB(T) and REX 326F have been used for marine high pressure rotors of this type. Low pressure rotors are usually made from ferritic steels, and may be solid forgings of molybdenum-vanadium steel, H46 or REX 448—depending on the operating conditions—or, in some cases, assemblies of discs of these steels. Some steels for forged rotors are given in Table III.

Reduction Gearing

Up to the end of the 1939–45 war period, few departures had been made from the use of 3½% nickel steels for the forged pinions for steam turbine reduction gears. These were either air or oil hardened and tempered to a minimum hardness of 185 Brinell, the mating material of the hollow-forged gear-wheel being medium carbon steel normalised to a hardness range of 137 to 163 Brinell. Departures from these materials arose for two main reasons: first, a need to conserve nickel, and second, the requirements in certain cases for steels of superior properties to withstand higher tooth loading and provide greater wear resistance. For the former a 3% chromium-molybdenum steel has been accepted for pinion forgings. The hardenability of this alloy is superior to that of the nickel steel and, in consequence, minimum tensile strength and hardness of 45 tons/sq. in. and 205 Brinell, respectively, are frequently required for pinion shafts and rims. With this higher hardness, a "40" carbon steel or a 1% nickel steel may be suitable for the gear wheel, the forging being normalised to a hardness of about 170 Brinell minimum. It is usual to ensure that the hardness of the wheel is less than that of the pinion, and at this range the difference usually exceeds 25 Brinell points. If 3½% nickel steels are required for pinions, with tensile strengths of 50 tons/sq. in. as in continental practices, the steel may also contain about 0·15% vanadium or 0·3% molybdenum to improve the hardenability. Nickel-chromium-molybdenum steels, in the oil-hardened and tempered condition, are the most suitable steels for pinions of higher hardness.

Oil Engine Pistons

Formerly cast irons predominated as the materials of both heads and skirts of pistons. Although they were usually ordinary grey irons, some pistons were made of low-alloy types. As cylinder pressures and temperatures increased, forged medium-carbon steel replaced cast iron for the cylinder head, but it is only recently, that other materials have been contemplated. A few years ago, one engine builder introduced a 13% chromium stainless iron. The heads were cast in either static or centrispun sand moulds. After rough machining, the heat treatment effected consisted of air cooling from 1,050° C. and tempering at 700–750° C. In service the centrispun castings have proved the better and are giving a satisfactory performance. While a chromium content of 20% might provide a stainless iron of superior heat-resisting properties, the additional cost does not appear to be warranted. More recently cast spheroidal graphite iron piston crowns have been used. This iron has been tried in the as cast, tempered and part-annealed condition. Although operational experience extends over a period of little more than three years, this iron has displayed adequate resistance to wear and thermal cracking. Its use is increasing for main and exhaust pistons, and a serious challenge may be presented to the forged-steel type.

Turbine Blading

The operating conditions of most marine steam turbine plants are such that martensitic stainless steels may readily form the blading materials. Stainless irons (13% chromium) predominate due to good fabrication characteristics and adequate creep properties up to 850° F. With a 0·5% molybdenum addition, these display superior creep properties and their use can be extended up to 880–950° F. Some use is also made of an alternative 0·5% titanium addition when service at 1,000° F. can be attained. However, at the lower temperatures, corrosion-fatigue strength is rated of greater importance, and a minimum of free ferrite in the structure of the steel is considered essential for optimum properties in each type.

TABLE IV.—SOME STEELS FOR TURBINE BLADING.

No.	Type	Composition						
		C%	Si%	Mn%	Cr%	Ni%	Mo%	Ti%
1		0·15 max.	0·45 max.	0·2/0·6	13 min.	0·5 max.	—	—
2		0·15/0·20	0·45 max.	0·2/0·5	12/14	0·5 max.	—	—
3		0·09/0·14	0·35 max.	0·25/0·5	11·5/12·5	0·5/0·8	0·4/0·6	—
4		0·10	0·7	0·8	18·0	8·5	—	0·6
5		0·30	—	—	11·5	35	—	—
6	F.C.B.(T)	0·12	0·6	1·2	18	11	—	Nb.-1·2

TABLE IV. (*cont.*).

No.	Typical or Specified Mechanical Properties				
	Yield Stress (tons/sq. in.)	Ultimate Tensile Stress (tons/sq. in.)	Elongation (% on 2 in.)	R. of A. (%)	Charpy (kg./sq. cm.)
1	18 min.	30/40	25 min.	50 min.	8 min.
2	32 min.	45/54	20 min.	—	8 min.
3	32 min.	45/54	20 min.	—	8 min.
4	18	42	45	—	17
5	25 min.	45 min.	20 min.	35 min.	—
6	—	40·5	57	65	—

The austenitic steels given in Table IV have both been used to varying extents in marine practice. The disadvantages of particular types, which include low yield stresses, high work-hardening rates, high coefficients of expansion and susceptibility to inter-granular corrosion, are all well known and are capable of being dealt with in design and manufacture.

There are many creep-resisting austenitic steels which could be selected for the blading of gas turbines. The high temperature strength properties and scaling characteristics of the various alloys have received great attention. To compete with other prime movers, the marine gas turbine inlet temperature must exceed 1,250° F., and the austenitic steels have been discarded in favour of Nimonics 80, 80A, and 90 for the blading of the high pressure rotor. If these or Nimonic 75 are unnecessary for the conditions of service in the low pressure section, the choice of F.C.B.(T) has been made. Where compressor blading is of steel, it is of the martensitic stainless types found in steam turbine practice.

Stationary Turbine Parts

Low pressure turbine casings of cast iron are generally of good quality, but casting stresses may be of high order. In consequence, it is usual for long-time low-temperature treatments to be given to these, as well as to steel castings used for high pressure casings. Such treatments impart thermal stability to the material and generally reduce any tendency for distortion in service.

The high pressure casings for gas turbines are cast or fabricated in Nimonic 75 or F.C.B.(T) alloys, which also form the components of the combustion chamber. Compressor casings are mainly of ferritic steel or cast iron. Ferritic steels are also adopted for the low pressure casings, 1% chromium-molybdenum types, 1% chromium-molybdenum-vanadium types, or 0·5% molybdenum–0·2% vanadium being preferred by manufacturers.

In some marine gas turbines the stator blades of the power turbines and compressors have been precision investment castings. Austenitic stainless steels of a 16–14 3 tungsten type form these components from heats of less than 15 lb. Some use is also made of this technique for the manufacture of impellers for exhaust turbo-superchargers, the weight of the casting being up to 40 lb.

Steam Plant

The incidence of caustic cracking in the mild steel plate forming the riveted seams of cylindrical boilers is still a matter of concern. Of late, the number reported has shown a decided increase and, as this type of boiler retains a certain amount of popularity, it is surprising that metallurgical research has not given greater consideration to the problem. The hollow-forged steel boiler is still prominent despite the trend towards fusion-welded types. These have given excellent service, but an instance is mentioned in which defects developed in the forged drums of the port and starboard water-tube boilers of one ship. These were cracks which originated from thermal fatigue due to excessive local heating of areas of the drums during service.

Electrodes which are available for welding pressure vessels and fabrications made of lower carbon steel plates with tensile strengths between 26 and 32 tons/sq. in., give deposits which vary considerably in both strength and hardness. Depending on the analysis of the rod and the type of coating, the composition of the weld metal may vary between 0·04% and 0·14% carbon, 0·40 and 1·40% manganese, and 0·05 and 0·5% silicon. Even in large butt welds which have been stress-relieved on completion, the tensile strength and hardness of the deposit will be much higher than those of a normalised forging or casting of similar composition. The lower limits of carbon and manganese will give a tensile strength of about 28 tons/sq. in. and the upper limits about 40 tons/sq. in. for heavy deposits of weld metal. The dangers which may accompany the laying down of small deposits or light runs on cold metal are not always appreciated. The quenching effect produces hardnesses approaching, and in excess of, 400 V.P.N. and cracking can easily result.

The majority of fusion-welded drums have been fabricated from steel plates having a carbon content of less than 0·28%. The assessed maximum working stresses in the steels have been limited to values not exceeding one quarter of the tensile strength, a figure universally accepted until recent years for maximum service temperatures up to 650° F. During post-war years carbon and alloy-steel drums with scantlings between 20 and 30% less than those complying with this safety factor have been manufactured in Germany for land and marine purposes. Design stresses for marine applications have been based on 0·59 of the minimum hot yield (or 0·2% proof) stresses of each steel at the optimum operating temperatuers. The safety factors on the tensile strengths are limited to 2·83 for carbon steels and 2·43 for alloy steels. The Germans are accumulating experience in the use of thinner scantlings,

but authorities of other countries are not convinced that reducing the safety factor below 4 is justified. With the trend to higher strength carbon and alloy steels to enable thinner drums to be made and to greatly increased size of drums for land steam plant, it would appear that some justification exists for moderate reductions in the safety factor for operating temperatures below 650° F.

So far as superheaters and steam pipes are concerned, marine practice is following that on land. With increasing temperatures the steels in order of rising creep- and scaling-resistance are carbon, carbon-0·5% molybdenum, and 2·5% chromium- 1% molybdenum. The long tempering times recommended for 0·5% molybdenum-0·3% vanadium steels are reducing their popularity, but the creep properties are superior to all other ferritic steels. The upper limit to which ferritic steels can be used is about 1,100° F., either creep- or scaling-resistance being inadequate at higher temperatures. Land practice regards an 18–8–1 niobium austenitic steel as the best choice in stressed applications where the temperature exceeds 1,100° F., but marine steam plant designers have avoided its use except for low-stressed parts which must have high heat-resisting properties.

Propellers

Cast irons retain a predominance over other ferrous materials for the manufacture of propellers. Following long-standing practice, simple grey irons which conform to B.S.1452 : 1948, grades 10–14 are generally used. Low-alloy irons containing principally nickel and molybdenum are also in service, the higher strength of these irons permitting some reduction in the scantlings of the propeller. During the past five years a number of spheroidal graphite iron propellers have been cast. They were put into service in the " as cast " condition and were all under 7 ft. in diameter. In service, however, the erosion resistance of low-alloy and spheroidal graphite irons have proved little better than those of the unalloyed grey irons.

Severe damage to cast iron propellers by cavitation erosion has long been a matter of concern. Spray coatings of zinc, lead and aluminium have been applied to give protection, and the aluminium coating was found to be the most effective, although spraying was necessary at frequent intervals. More recently cathodic protection has been tried, both by sacrificial magnesium-aluminium alloy anodes and applied-current methods. The results have been most encouraging, especially with sacrificial anodes attached to the propeller boss or stern of the ship. For ships which navigate in ice waters, medium carbon steel cast propellers have been preferred for many years. Tougher steels are used for the propellers of ships in ice-breaking service. Both a nickel-vanadium steel (0·18% carbon, 1·5% nickel, 0·15% vanadium) and a 3·25% nickel steel have proved satisfactory, but their corrosion- and erosion-resistance are not appreciably greater than carbon steel castings. Suitable chromium-base ferritic steels have been developed for propellers. In Sweden, following extensive experiments, a 0·12% carbon, 13% chromium, 1% nickel, 1% molybdenum, steel was adjudged the best, and has been used extensively for small and large propellers. In service it has high resistance to corrosion and cavitation-erosion.

Long-Welded B.R. Rails

THE most recent installation of long-welded rails completed on British Railways is a length of 1,800 yd. of track at Crewkerne in the Southern Region. The rails were first welded in a depot into lengths of 300 ft. by the electric flash-butt method, and these lengths were subsequently joined at site by Thermit welding. The rail is laid on concrete sleepers and the finished track contains reverse curves of 100 and 58 chains radius. Thirty-five trains a day travel on this line at speeds up to 80 m.p.h.

This development follows the laying in of experimental lengths of long-welded track on goods lines at Syston, London Midland Region, and at Llanwern and Treforest, Western Region. The welding of the rails was done in the same way, except that all the joints on the Treforest length were Thermit welds throughout. Prior to this, rails had been welded experimentally into lengths up to 300 ft. only. Concurrently with laying in the longer lengths, laboratory tests have been carried out to establish the necessary safeguards required to prevent distortion of the long rails in hot weather, and very careful measurements are being made and recorded of the movements of the rails undergoing these tests. Experimental trials in the use of long-welded rails have previously been made on the Continent and their use is now being considerably extended, but continental traffic conditions and occupation facilities differ considerably from those on British Railways.

So far as the welding of the rails is concerned, the best method hitherto evolved is that of electric flash-butt welding but this can only be done at present by stationary plant in a depot. Rail is therefore welded by this method into lengths of about 300 ft. and these lengths are then transported to site and joined there by Thermit welding. British Railways already have two flash-butt welding plants and another four are on order, which will enable a considerable extension in the use of long-welded track in future, in keeping witht the Modernisation Plan.

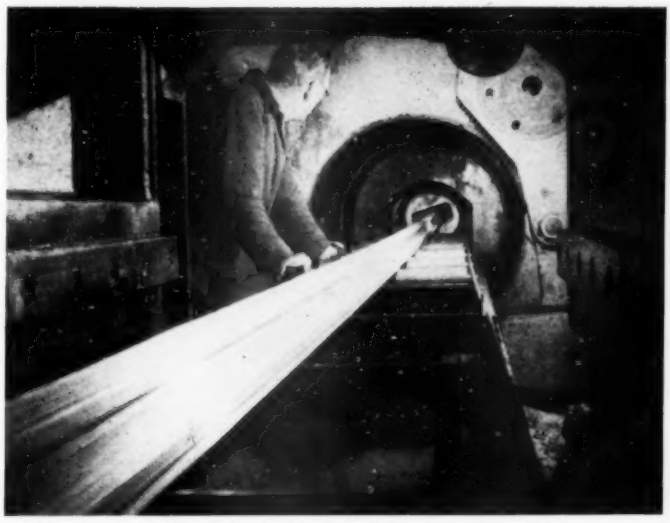
New Hungarian Ore-Dressing Plant

HUNGARY is to build an ore-dressing plant at Rudabanya near the Czechoslovak border in the north-east of the country to process large deposits of low-grade siderite found there. The machinery is now being manufactured by the Ernst Thalmann Works in Magdeburg, Germany. It is estimated that when the plant is completed in 1958, it will be possible to raise Hungarian ore production to two and a half times what it is today. Work has begun on the site with the erection of 800 flats for the future workers.

Brown iron ore has been known in the area since 1200 A.D., but it is only in the last century that any appreciable quantity has been mined. Even up to the last war most of the work was done by hand. In the last ten years, however, owing to the growing capacity of the Hungarian metallurgical industry, there has been considerable mechanisation. Drilling cars and loading machines were obtained from the Soviet Union and East Germany, and hammer drills from Austria. The dressing plant will make use of large quantities of low-grade ore that was previously wasted.

Extruding Aluminium Alloy Sections

New British Aluminium Plant at Latchford



Extrusion emerging from die.

SITUATED alongside the Manchester Ship Canal east of Warrington, the Latchford Locks factory of the British Aluminium Co., Ltd., was put down initially as a Government-sponsored scheme for light alloy scrap reclamation and aluminium powder production during the war. Following its acquisition by the Company at the close of hostilities, milling and mixing plants were added to existing powder blowing facilities, for the production of paste, which forms the basic ingredient of aluminium paints now widely employed for the protection, and sometimes the finishing, of structural and other steelwork.

While the factory has hitherto continued predominantly as a light alloy scrap conversion unit for the production of foundry alloys, specialised casting equipment and techniques have been developed for the production of light alloy rolling blocks and wirebars. Thus it was a short step to the production by semi-continuous casting procedures of extrusion billets to meet the requirements of the new extrusion development.

The British Aluminium Company have been engaged in the production of aluminium and aluminium alloy extrusions since 1911, and for many years this branch of the Company's activities has been concentrated at the Warrington factory, which is also a sheet and strip rolling mill. Presses ranging in capacity from 600 tons to 2,500 tons have constituted the extrusion capacity hitherto, but developments in the aluminium alloy structural, marine and transport fields involve heavier presses to meet the demand for larger sections in strong and medium strength alloys, for supply either in the "as extruded" condition or subsequently heat treated. Foreseeing these developments, the Company some time ago acquired under reparations arrangements a 5,000 ton press and a 3,500 ton piercing press, both of Schlömann manufacture, along with heavy section stretching plant. These two press units form the basis of the new extrusion scheme at Latchford.

Site and Buildings

The land owned by the Company at Latchford Locks totals some 70 acres, of which the parent factory buildings occupy about 4 acres. Adequate space existed, therefore, in which to set down the new extrusion factory which with its associated subsidiary buildings, occupies an area of 1½ acres. A site was chosen to the north west of the parent works such that, while the haul for cast billets prepared in the parent remelt shop and for returning process scrap is kept to a minimum, ample scope exists for expansion of the new factory. The production plant is housed in a single bay of 106 ft. span and 550 ft. length, while the toolroom forms an annex 40 ft. wide and 100 ft. long on the west side.

The building itself, which comprises a steel structure double-skinned in corrugated aluminium sheeting, is described in detail later. The heating system, which is based on a scheme of radiant panels, is also dealt with in the description of the building.

Services

The electricity service calls for no particular comment, supply being taken at 6 kV. from an Area Board sub-station within the site boundary and distributed over a 6 kV. ring main to consuming points and step-down sub-station. The choice of 6 kV., while convenient for primary distribution, was in this case specifically required to serve certain of the hydraulic pressure pump motors which are wound for high—tension supply. Final distribution throughout the factory is at 415 volts 3 phase. Extensive use has been made of distribution cabling in which both core and sheath are of aluminium. The building is lighted by 5-ft. fluorescent lamps at roof tie level.

Water supplies presented something of a problem, in that considerable quantities are necessary for section-quenching at heat treatment, for which the town's water service was inadequate. Use of Ship Canal water for this purpose necessitated elaborate precautions for the removal of suspended solids and slimes in order to avoid the risk of product staining. Water is, therefore, pumped from the canal to a break pressure tank, and thence through a self-cleaning Glenfield and Kennedy micro-strainer to a settling pond of 1,000 sq. ft. surface area. By this means clear water is available on which secondary supply pumps draw for the cooling water service in the factory, which is maintained at a pressure

of around 75 lb./sq. in. A separate booster pump is available to establish a high pressure jet quench at each of the presses when required.

Production Plant

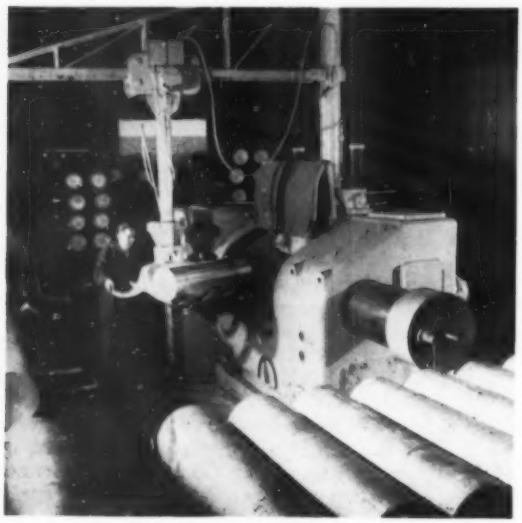
Remelt Shop

Metal is cast into extrusion billets from two fixed-hearth, oil-fired melting furnaces in the parent factory remelt shop, the furnaces having bath capacities of 8 and 5 tons, respectively, and forming part of the former parent remelting capacity. These furnaces serve two screw-type semi-continuous casting machines having a range of electrical speed control from 0 to 15 in./min. Billets ranging in diameter from 10 in. to 16 in. are produced on these machines, which will ultimately handle cast stock up to 20 in. diameter.

After extraction from the casting machines the billets are cut to length on a Noble and Lund 60 in. Flui-feed saw which will accommodate the full range of billet sizes. For certain alloys and end products the billets are then scalped in a machine made by Wirth, of Germany, in which billets up to 37½ in. in length and 16½ in. in diameter can be machined to a depth of ⅜ in. in a single run at cutting speeds up to 2,920 ft./min. and feed speeds ranging from 40 to 60 in./min. The machine is powered by a 100 h.p. two-speed motor. Built-in billet handling facilities reduce idle time to a minimum, and pneumatically operated centre grips ensure rapid positioning of the billet in the lathe. Cast billets sawn to length and scalped where necessary are then available for transport to the extrusion factory.

Extrusion Plant

The two reheating furnaces, one for each press, are identical. Supplied by G.W.B. Furnaces, Ltd., they are of the electric resistance type, and are designed for heating billets up to a maximum temperature of 650° C., depending on the alloy concerned. Each furnace is rated at 715 kW. divided into three independently controlled zones. To ensure even and rapid heating, five forced air circulating fans are located in the roof of the furnace. The heating elements are suspended from the roof and are separated from the working chamber by heat resisting steel sheet, so that direct radiation on to the charge is avoided, and a directional air flow is obtained, down the ducted sides, up through the hearth, and back to the fans. It is estimated that a thermal efficiency of over 80% is obtained, with a power consumption of less than 195 kWh/ton of billets heated to 600° C.



Scalping the billets.

The billets are conveyed through the furnace on a series of eight heat resisting steel chain type conveyors, four chains for each of the two rows of billets passing through. Each row can be operated independently, and there are two individually operated doors at each end of the furnace. At the charging end, the billets are raised from floor level by electrically operated hoist, and at the discharge end they roll down an incline under the control of suitable stops, which release them one at a time on to transverse driven diabolo rollers as the adjacent press requires them.

Both the 5,000 ton and the 3,500 ton presses are served from a common hydraulic installation operating at 240 atm. (3,600 lb./sq. in.). The hydraulic medium is water, with the addition of a corrosion inhibitor, and the accumulator system comprises a total of thirteen steel bottles, of which eleven are under air pressure and two are air/water bottles. The length of each air bottle is

General view of the plant : billet storage in foreground ; 3,500 ton press on left ; 5,000 ton press on right ; heat treatment furnace in background.

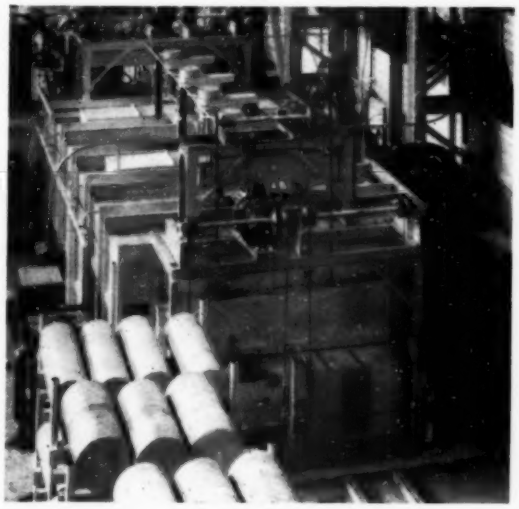
approximately 21 ft., with an overall diameter of 3 ft. and a wall thickness of approximately 3 in. Each bottle weighs 13 tons and has a cubic capacity of 560 gal. The hydraulic system is supplied from a total of five positive-displacement fixed-delivery three-throw pumps having a total capacity of 450 gal./min. and a total pump horse-power exceeding 2,000. Air compressor equipment is available for initially charging the air hydraulic system, and for making good any air loss.

The presses themselves are served for container and die change purposes, also for general maintenance, by a 25 ton E.O.T. crane of Morris manufacture with a 5 ton auxiliary hoist.

The 5,000 ton extrusion press, of Schlömann design and manufacture, is a four column unit having a total

weight of some 350 tons, the main ram of which is 54 in. diameter and has a maximum stroke of 100 in. Container heating is by induction, the conductors forming an integral part of the container mass. Die sealing is effected by hydraulic rams operating under full system pressure, while the press is equipped with a run-out table 36 ft. long, beyond which may be positioned a power driven coiler for the drum coiling of extruded tube. The press is capable of accepting billets ranging in size from 10 in. to 20 in. diameter, and in lengths up to 45 in., and billet discard is removed from the die by a vertical hydraulic shear.

The 3,500 ton press incorporates a piercing ram of 500 tons thrust, with the main ram capable of exerting 3,000 tons pressure. When the press is not engaged on piercing



View of reheating furnace from charging end.

operations, however, the total pressure of 3,500 tons can be exerted. This press, which weighs approximately 250 tons, is of the three column type, and has a main ram diameter of 54¼ in. with a maximum length of stroke of 83 in. Die sealing is by wedge action, but container heating and discard removal arrangements are similar to those on the 5,000 ton press. The press is capable of accepting billets ranging from 8 in. to 12 in. in diameter.

Both presses are equipped for automatic handling of billets and pressure plates ; they are also furnished with extrusion speed indication and die heating facilities mounted adjacent to the production plant.

Heat Treatment Plant

Of a type exclusively developed for the solution and precipitation treatment of aluminium alloy sections, the Birlec furnace consists basically of a 60 ft. heating chamber divided longitudinally into two parts, one above the other. Air circulates at a velocity of 80 ft./sec. through a lower chamber, is deflected through 180° by special vanes at the door end of the furnace and returns along the upper chamber. This unusually high air flow rate which ensures temperature differences of only ± 2° C. across the charge, is achieved by a baffled twin entry fan which is powered by an 80 h.p. motor and has 5 ft diameter fans operating at 550 r.p.m. Heating is by sinuous elements arranged to give an electrical loading of 500 kW.

The furnace is designed to handle aluminium alloy

Close-up of 5,000 ton press.

sections varying from 2 × 2 in. angle up to 12 × 6 in. channel in lengths up to 60 ft. For solution treatment at temperatures around 500–550° C. the charge load is of the order of 0·8 tons, the figure for low-temperature precipitation being 4 tons. Charges are loaded on to articulated steel skips, 5 × 1 × 60 ft., which run on roller tracks in the furnace, mount the quench platform and run on a double row of idle rollers. By means of a system of hydraulic cylinders, this platform is rapidly lowered into the quenching medium, the charge entering the quench at a slight angle to prevent entrapment of air or steam. Running along the length of the quench tank, which is sunk below floor level in front of the furnace, is an electrically operated bogie head which traverses the charge into the furnace and extracts it when required.

Section Stretching Plant

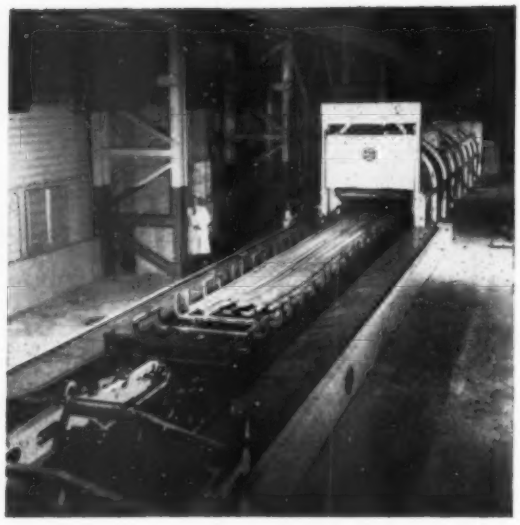
The section stretching plant comprises five machines, brief details of which are listed below :—

Manufacturer	*Max. pull (tons)*	*Section Length Accepted (ft.)*	*Source of Hydraulic Supply*
1. Fielding & Platt, Ltd.	30	80	Self-contained oil pump. 2,240 lb./sq. in.
2. Joshua Bigwood & Sons, Ltd.	100	50	Central water system 3,600 lb./sq. in.
3. Joshua Bigwood & Sons, Ltd.	150	80	Central water system. 3,600 lb./sq. in.
4. Kieserling and Albrecht.	200	50	Self-contained pressure system (oil). 1,760 lb./sq. in.
5. Schlömann	585	47	Central water system. 3,600 lb./sq. in.

The 100 ton, 150 ton and 585 ton stretchers are each equipped with facilities for de-twisting sections under tension and, furthermore, the 585 ton unit has a potential design capacity of 700 tons when equipped with a self-contained hydraulic supply at 300 atm. Provision has also been made in the foundations of this stretcher for later extension to cater for 75 ft. finished lengths of section.

Section Finishing Equipment

In addition to section saws, the finishing equipment includes 30 and 40 h.p. multi-roll straightening machines,



Furnace for solution and precipitation treatment, with quenching tank and cradle in foreground.

a Henry Berry 100 ton horizontal bending and straightening press, together with profile correcting machines, etc. The finishing plant and warehouse are served by two 7½ ton E.O.T. cranes 100-ft. span supplied by S. H. Heywood & Co., Ltd. Case storage, packing, warehousing and despatch facilities are located at the northern extremity of the building.

Toolroom

A well equipped toolroom forms an annex on the west side of the main building. Facilities are available for the machining and heat treatment of the dies used in the extrusion presses.

Range of Products

The Latchford extrusion plant as it exists at present is capable of producing a wide range of extruded sections, including all those covered by B.S.1161. Sections in the fully-heat-treated condition can be supplied up to 55 ft. finished length, while non-heat-treated sections up to a maximum of 75 ft. can be produced. Thus, the Latchford development represents a valuable addition to the Company's range of extrusion capacity in that the type and size of product is complementary to that produced at the neighbouring Warrington Bank Quay Works.

The Buildings

Foundations and Flooring

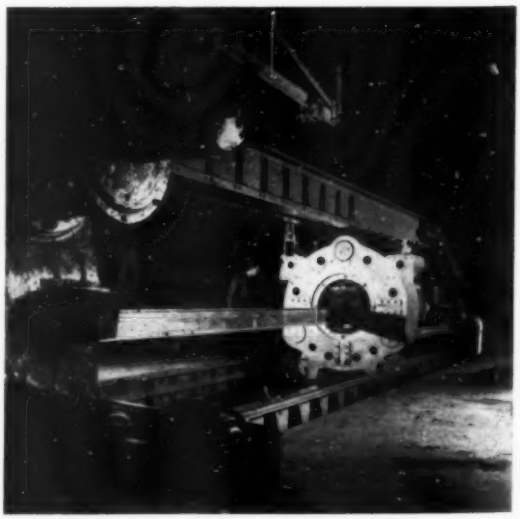
In view of the relatively heavy loading required in portions of this building, the foundations presented a special problem because of the poor bearing capacity of the ground. Test bore-holes were made over the area, and these showed that at least the top 20 ft. of ground was composed of silt, peat and running sand, and that the water table was only approximately 4 ft. below ground level. As a result of these investigations, it was decided to disregard the top surface of the ground for bearing purposes, and to carry the loads of the building structure and plant foundations on piles driven to an average depth of 40 ft. into red marl clay and sandstone.

The portion of the building in which the heavy plant was to be situated necessitated a loading of 15 cwt./sq. ft., for which 17 in. diameter piles were driven on a grid of 6 ft. 3 in. centres, the remainder being on a grid of 8 ft. 4 in. centres for a loading of 7½ cwt./sq. ft. Additional piles were inserted for the bases of the building stanchions. The 12½ in. thick reinforced concrete floor throughout the building has been designed as a beam spanning from the pile caps and attached to plant foundations where the thickness of these necessitated cutting off the piles at a lower level.

The site was raised about 3 ft. above natural ground level with consolidated hard red shale and the concrete floor laid on this, thus dispensing with timber shuttering except around foundation bases, ducts, pits, etc. Prodorite Ferrogran tiles were laid on the main passageways and areas of the floor which are subject to heavy wheeled traffic, and the remainder of the floor finished in granolithic. Covers for ducts, pits around portions of the plant and the treads of the access ladders to the cranes are made of aluminium P.G.P. Heavy Pattern treadplate, and aluminium tubing was used for the handrailing around plant enclosures.

Roof and Walls

The main building, which is 550 ft. long, is of fairly conventional steel construction designed to carry one 25 ton and two 7½ ton cranes, the span between crane rails being 100 ft., with a height to truss tie level of 30 ft. The profile of the truss is of Mansard type and allows stretches of patent glazing on either side of the building above the eaves, together with a continuous lantern of patent glazing along the ridge for the full length of the building, giving a good distribution of light over the whole shop floor. Provision has been made for attaching, on 250 ft. of the west side, a structure of similar span, and the north gable can be removed to extend the length of the present building if necessary. Attached to the west side of the main building is a 40 ft. wide toolroom, 100 ft. long, which can be extended to 200 ft. Ancillary buildings comprise boiler house, substation, office and lavatory accommodation. The roof of the main building, which has a 5° slope with purlins at 6 ft. 9 in. centres, is covered with Anderson's aluminium E decking, comprising 19 s.w.g. corrugated aluminium decking (fabricated by The British Aluminium



585 ton stretching machine with de-twisting heads.

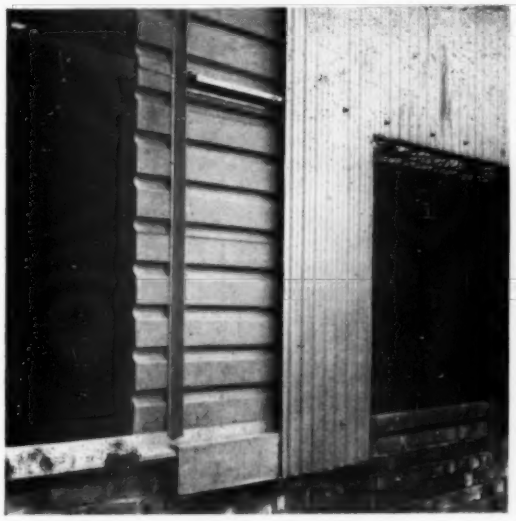
Company), ½ in. insulation board bonded in bitumen compound and covered with two layers of Rokbond bitumen roofing, continuously bonded in bitumen compound, the surface dressed with bitumen and finished with gravel.

The walls are clad by the Dialindre method, developed by Freeman, Morrison, Ltd., which comprises a double skin of corrugated aluminium sheeting spaced 2 in. apart by folded aluminium distance pieces. The outer skin in this case is Rigidal 3 in. pitch corrugated sheet of 20 s.w.g., normally laid, and the inner skin Rigidal Mansard sheet of 24 s.w.g. with the corrugations running horizontally. This inner skin has been Alocrom treated to give a pleasant appearance. The roof and walls of the toolroom are similarly treated, but here the inner skin in addition to being Alocromed is also stucco embossed.

The U value of Dialindre double skinned sheeting is of the order of 0·27, and although it has not been possible to ascertain the heat losses during the winter months, tests were carried out during the past summer which showed that on an average the temperature inside the building was 10° F. lower than in an adjacent building covered with a single skin of corrugated aluminium sheeting. The building is ventilated naturally with roof ventilators and inlet louvres low down in the side sheeting.

Heating

Heating is by high pressure hot water supplied by a Danks (Netherton) boiler, which is Clyde Automatic oil fired and has a capacity of 5,800,000 B.th.U./hr. and a working pressure of 120 lb./sq. in. Eighty-eight radiant panels, each 8 ft. × 4 ft., fixed adjacent to the walls below crane gantry level, and five unit heaters at truss tie level, maintain a thermostatically controlled internal temperature of 60° F. with 1½ air changes per hour. The boiler has an excess capacity of 28%, but provision has been made in the boiler house for an additional boiler to cater for future extensions to the building.



Close-up of external wall cladding, showing the Dialindre lining.

Additional office accommodation was obtained by attaching to the general offices of the adjacent parent factory a single storey Hawksley prefabricated aluminium building which provided a rapidly-erected permanent structure.

Rolling Mill Modernisation at Workington

Workington Iron & Steel Company, in Cumberland, a branch of The United Steel Cos., Ltd., are spending over £1 m. on a scheme for modernising their steel rolling mills, which make rails and other railway materials for railways all over the world. The scheme falls into two major sections—the replacement of two old steam engines which drive the roughing and finishing stands of the rail mill by two electric drives, and the reconstruction of another smaller mill which is mainly engaged in rolling the bars from which fishplates and bearing plates are produced.

The rail mill is being moved 40 ft. from its present position, with the dual objective of obtaining a layout designed for higher production and to enable the reconstruction to proceed without seriously interrupting the present output. The smaller mill, known as the fishplate mill, is being moved about 80 ft. from its present position, which will allow almost the whole of the installation to proceed without interfering with the working of the present mill.

Reconstruction of the fishplate mill, which is expected to be completed by the end of this year, will enable output to be stepped up from 7,800 to 11,400 tons per annum. The new electric drives for the rail mill are planned to be in service by next May. The modernisation scheme is expected to lead to more efficient working with considerable economies in fuel and maintenance costs. Much new ancillary equipment is also being provided, including overhead cranes and a reheating furnace. Already, an entirely new roll turning shop and a hydraulic pump and air compressor house have been erected and are in service.

B.T.H. £400,000 Australian Order

The British Thomson-Houston Co., Ltd., have received through their associated company, Australian Electrical Industries Pty., Ltd., an order worth approximately £400,000 for the Broken Hill Proprietary Co., Ltd., Australia. This covers the electrical driving equipment for an 18 in. continuous steel strip and skelp rolling mill to be installed at the Broken Hill Proprietary Co.'s Newcastle Works, New South Wales. The B.T.H. plant includes fourteen D.C. motors totalling 9,800 h.p., two 3,500 kW. banks of grid-controlled mercury-arc rectifiers for supplying electric power to the motors, together with control gear.

Hadfield's Scottish Representative

Hadfields, Ltd., have appointed Mr. J. Hanscomb and Mr. G. E. Gill as their Sales Representatives in Scotland, succeeding Paul & Macleod, Ltd. They have acquired the office accommodation previously occupied by Paul & Macleod at 82, Gordon Street, Glasgow, C.1, and their Scottish sales representation is now conducted from that address. Mr. Hanscomb moves to Glasgow from Hadfields' Sales Staff in Sheffield, and since 1949 Mr. Gill has been with Paul & Macleod, Ltd.

International Flame Research

Progress Surveyed at Furnace Inauguration

The ceremony of inauguration of the pulverised fuel furnace and plant of the International Flame Research Committee was held last month at the Committee's research station at IJmuiden, in Holland. We present here those sections of the addresses given by Professor G. M. Ribaud (President of the Committee) and Dr. D. T. A. Townend (Director General of the British Coal Utilisation Research Association) which dealt with the work at IJmuiden.

READERS may recall that the June 1954 issue of this journal featured an article* on the new research station built for the Flame Radiation Research Joint Committee at IJmuiden in Holland. Reference was made to the origin of this international organisation, which was set up to study the radiation properties of luminous flames. In response to numerous demands made by contributors to the work of the Committee, certain of the trials have been orientated towards a study of the thermal exchanges which take place by convection between the flame and a cold load, a problem which is of the utmost importance to those concerned with furnace practice in the steel industry. This modification of the original aims is reflected in the somewhat more comprehensive title by which the Committee is now known, viz., International Flame Research Committee.

The earlier article included descriptions of the furnaces and research equipment which would be available in the new station, although at the time the pulverised fuel fired furnace referred to was not completed—in fact little more than the foundations existed. Work on the construction of this item has continued during the past year, and on Saturday, 12th November, 1955, the Ceremony of Inauguration of the new Pulverised Fuel Furnace and Plant took place at IJmuiden, in the presence of some 80 representatives of the National Committees supporting the work. The Inauguration Day was marked by two events of importance to the work of the Committee. In the first place, the Flame Radiation Research Joint Committee was officially incorporated under Dutch law as the International Flame Research Foundation, with the International Flame Research Committee as the governing body. Secondly, an amount of 300,000 florins (£28,500) was received from the Haute Autorité de la Communauté Européenne du Charbon et de l'Acier towards their gift to the Foundation of 400,000 florins (£38,000).

The representatives were addressed by the President, Professor G. M. Ribaud; the Chairman of the Managing Directors of the Royal Netherlands Blast Furnaces and Steelworks, IJmuiden, Mr. A. H. Ingen Housz; and M. Léon Daum, Member of the Haute Autorité de la Communauté Européenne du Charbon et de l'Acier. Dr. D. T. A. Townend, Director General of the British Coal Utilisation Research Association delivered an address on the combustion of solid fuels and the aims of flame radiation research.

Presidential Address

Following a brief introduction in which he welcomed the support of the Haute Autorité, Professor Ribaud proceeded to retrace briefly the different lines of research pursued by the Committee's engineers.

Immediately after the first trials, agreement was reached as to the necessity of adapting and even creating the measuring instruments required to assess the value of the several variables which it was wished to study within the flames—e.g., velocity, temperature and composition of the gases, radiation from the flame at different points, etc.—and in view of the large number of readings which had to be made simultaneously, it was found essential to develop recording technique to the utmost.

Some of the instruments gave satisfactory results relatively quickly; others, on the other hand, required a somewhat laborious development, as, for instance, the suction pyrometer for use at temperatures up to 1,650°C., the instrument for measuring the local radiation from the flame, and the apparatus developed for the sampling and analysis of carbon particles. In this field, an important contribution has been made in creating prototypes which have already found a welcome application in industry.

As to the experimental work, the trials have been of two kinds: the first, performance trials, in which the measurements are confined to overall readings bearing on the size of the flame and its total radiation at the different points of its passage through the furnace; measurements which are essential in assessing the heat transfer to the walls, or the load.

Seven series of such trials, spaced out between the years 1949 to 1955, have been carried out, each lasting over a period of fifteen days to three weeks, with three teams of experimenters working eight hours per day.

A continued atmosphere of cordiality exists among these teams, composed of engineers of many nationalities, who come from a variety of industries. Indeed, many of them, for the most part young men, have referred to the benefit they derive from contact with the realities of heat transfer in its different aspects. On the other hand, a sense of obligation is owed to those industrialists who have been prepared to do without the assistance, sometimes for weeks at a time, of some of their engineers.

The performance trials were carried out on diffusion flames with two liquid fuels—heavy fuel oil and creosote pitch—and with coke oven gas, pure or carburetted, using various percentages of tar products. These have shown the overall importance of the influence of fuel jet momentum on the dimensions of the flame and its radiation. They have made it possible to give a quantitative value to the influence of the various input variables, viz., the type, quantity and inlet temperature of the fuel; the type of burner and atomising agent

* METALLURGIA, 1954, **49**,265-270.

and steam ; and the quantity, temperature and jet momentum of the combustion air.

These studies, of an essentially practical nature, have already borne fruit ; several industrialists have already advised the Committee of the improved efficiency obtained in their furnaces through the use of burners and atomising agents made more suitable for their requirements, and there is no doubt that a judicious application of the many recommendations contained in the written reports on the trials, will enable them to secure even more substantial gains. This is particularly true of users of transparent flames from producer gas, coke oven gas, and town gas installations, who would undoubtedly increase the utilisation efficiency of their gas through carburetting.

Combustion Mechanism Trials

The Committee might have confined its work to such trials of an industrial character, but it was convinced of the need to secure a more fundamental understanding of the phenomena which exist within the diffusion flame, so that the results obtained in the IJmuiden furnace could be extrapolated to other furnaces operating in different conditions. Such trials, called scientific trials, or combustion mechanism trials, implied, apart from the external measurements of the flame, a detailed study at each point of the flame, of the value of the variables : velocity, chemical gas composition, carbon content, temperature, and local radiation. With the first measurements, it became clear that the one important factor which controls the size and the radiation of the flame is the mixing history of the combustion gas injected into the furnace with its surrounding combustion air. It is visualised that combustion at first taking place only on the outer periphery of the jet can only penetrate to the interior by means of the progressive diffusion of the air towards the jet axis. Indeed, experts in fluids mechanics have already studied the relatively simple behaviour of a free jet of gas taking place within the unrestricted atmosphere of another gas, and they have shown in particular the important part played by the jet momentum of the injected fuel, but, in industrial practice, the problem proves to be of a more complex character ; on the one hand, because of the non-uniform rise in temperature resulting from the combustion, and, on the other, owing to the fact that the products of combustion cannot diffuse away into a free atmosphere, but are arrested by the furnace walls, and re-cycled within the flame with the combustion air with which they become mixed. High speed cinematograph films taken during the trials clearly indicate the "re-circulation" of incandescent particles of a fuel projected outside the flame. It seems clear that this "re-circulation" of the combustion products cannot usefully be tackled by a mathematical approach, and this has led to a study of it by means of models, either by means of the classic methods of visualisation of gaseous streams, or by careful analysis of the proportion of the injected gas (CO_2 for instance) present in the various layers surrounding the jet. These model studies, carried out in suitable similarity conditions have shown satisfactory agreement with the observations taken on the actual flame. In fact, divergencies not exceeding 15% have been observed in certain conditions, and a separate panel is at the moment studying the causes of these discrepancies.

The mixing processes are clearly not the only factors which determine the development of the various characteristics within the flame, in particular the chemical composition and, allied to this, the temperature. At a given point, the reaction velocity, that is to say, the amount of heat released per unit of volume, not only depends on the local temperature, but also on the chemical composition of the mixture in the zone immediately preceding the given point, a chemical composition which proves to be very complex.

Laboratory studies on the influence of temperature and of various gases, such as air, CO_2, H_2O, in the cracking of hydrocarbon particles, have confirmed the complexity of the problem. However, given the results of the observations on real flames, and coupling these with the laboratory results, it is nevertheless possible to establish some general relations of a relatively simple character which determine the quantity of free carbon at a given point, as a function on the one hand of the time taken for the gases to reach this point from the burner, and on the other, of the carbon content of the fuel. This study has also made possible the preparation of a quantitative classification of fuels in terms of their ability to produce carbon particles within various types of flames. Hydrocarbons of high C : H ratio, for instance, prove, all other things being equal, to be more apt to produce free particles, which so greatly influence the thermal radiation.

Heat Exchange Studies

In response to numerous demands made by contributors, certain of the trials were orientated towards a study of the thermal exchanges which take place by convection between the flame and a cold load, a problem which is of the utmost importance to those concerned with furnace practice in the steel industry.

There was special interest in the role which might be played in these heat exchanges by what has become known as *convection vive*, that is to say, the convection produced by a flame in which the chemical reactions are not complete, and where can be brought about, in the gaseous layer slowed up by its contact with an obstacle, a completion of the reaction, and, as a result, a local raising of the temperature favourable to a greater heat transfer.

A first series of measurements has been conducted ; the convection coefficients measured are in good accordance with the classic formulae, and at least for the particular flames studied, and with loads at relatively low temperatures, do not appear to call for the intervention of *convection vive*. Further measurements will be conducted on this subject.

In parallel with the work carried out at IJmuiden, a number of laboratories in Great Britain, the Netherlands, Sweden and France, have made an important contribution to the work of the Committee, through their study of the development and calibration of measuring instruments and also through their operation of experimental scale models of the industrial furnaces, which have given a valuable check on the results obtained at IJmuiden.

In the pulverised fuel field, reference cannot be made to results : the final touches required for the correct operation of the ancilliary equipment of the new furnace, are just being completed, and the first trials are due to begin at once. They will be directed towards the programme established by a special Sub-Committee

composed of the representatives of the various organisations particularly interested in pulverised fuel, organisations concerned with coal research and its utilisation, power stations, the water tube boiler industry and the cement industry, and others.

Dr. Townend's Address

Dr. D. T. A. Townend, Director General of the British Coal Utilisation Research Association, in introducing his address on "The Combustion of Solid Fuels, and the Aims of Radiation Research in Relation to the Burning of Pulverised Coal," pointed out that the present is a critical time in the history of the production and utilisation of coal. In Britain, for example, technical progress development in these fields had to be surveyed against the following trends : (*a*) an increasing gap between coal production and the needs of expanding industrial consumption ; (*b*) an increasing proportion of mined coal produced in the smaller size ranges, and frequently with a high mineral matter content ; (*c*) an increasing awareness by the public of atmospheric pollution, particularly by the use of solid fuels, and proposed legislation to deal with the problem ; and (*d*) a reluctance on the part of young men to take up mining as a career. It would be obvious, said Dr. Townend, that the full impact of such important trends was making heavy demands on those primarily concerned both with winning coal and with improving the methods of its utilisation.

Dr. Townend then proceeded to discuss, in the first part of his address, the combustion of solid fuel, beginning with a description of the form of some well-known fuel/air systems, stressing their present importance and main characteristics. This was followed by a simple description of the known chemical reactions which occur during the burning of solid fuels, and the experimental methods by which the respective contributions of these various factors have been assessed. Dr. Townend then gave a brief summary of the factors which control the rate of chemical reactions, stressing the conditions under which chemical and physical factors predominate. Particular attention was, naturally, paid to pulverised fuel combustion, and a brief outline of the main researches contributing to our understanding of the processes concluded the first part of the address. This last section of Dr. Townend's remarks is presented here, together with his comments on the investigations into oil-, gas- and solid-fuel-firing in the IJmuiden furnaces, in the course of which he first referred briefly to previous work, and then indicated what is proposed in special relation to the forthcoming experiments using powdered coal.

Pulverised Fuel Combustion Research

Since in a pulverised coal flame, the ratio of gas space to particle volume, is so much greater than the corresponding ratio in a bed of slack coal, a knowledge of the history of a single isolated particle of coal during its lifetime seems of greater interest than when it forms part of a fuel bed. Research work on the fundamentals of pulverised fuel combustion may therefore be conveniently divided into two parts : (*i*) the behaviour of single particles ; and (*ii*) the behaviour of assemblies of particles.

Reproduction of the shock heating conditions imposed on a small pulverised fuel particle after it enters a furnace is not easy in the laboratory, and usually particles rather larger than p.f. particles have been employed. Three stages may be recognised: (*a*) a pre-ignition stage accompanied by changes in size and shape and loss of some volatile matter, (*b*) ignition and combustion of volatile matter, and (*c*) combustion of residual coke. The experimental techniques applicable are limited and recourse has normally had to be made to high speed photographic methods. Of considerable interest in relation to stage (*a*) is the formation of cenospheres, which are hollow particles of considerably greater volume than the parent coal particles. They are formed from the bright components of coal but not from durain : their formation appears to be due to the combined effects of gas evolution and low plasticity under rapid carbonisation conditions. Photographic traces provided the first real data available concerning the ignition of evolved volatile matter. At about 800° C. furnace temperature, the burning time of the volatile matter appears to be 5–10 milliseconds for coal particles at 80–90 mesh. Recent work using a more refined photographic technique has enabled the temperature history of burning particles to be mapped.

An important property of pulverised fuel in relation to large scale practice is the question of initial ignition of the fuel. Whilst very different absolute values have been reported by different investigators, it is agreed that over the extreme range of rank from anthracite to low rank bituminous coal, minimum furnace temperatures for ignition vary by 200–300° C., being naturally lowest in respect of low rank fuels.

Knowledge of the combustion mechanism of the residual coke in pulverised fuel flames is mainly a matter of extrapolation from the behaviour of macroscopic particles, but it seems fairly definite that once ignition is established, most of the burning time is spent in consuming the residual carbon. Attempts to calculate these burning times are based on a mass transfer approach, diffusion being the controlling factor. Fair agreement has been obtained between calculated and measured values, but this does not necessarily justify all the assumptions made.

Only a limited amount of work has been reported upon semi-scale work relative to pulverised coal combustion. Prominent among the earlier workers were Audibert and Sherman, whose furnaces dealt with about 100 and 200 lb. coal per hour, respectively. At the time of this work, pulverised fuel firing under boilers was only just being established and the intention of the experiments was to provide data immediately applicable to large scale practice. Sherman's data in particular seemed to be consistent with what information on large scale practice was then available. His main findings were that (*a*) the amount of unburned carbon at first fell sharply with residence time and then more slowly, (*b*) the rate of burning increased with the volatile matter content of the fuel, and (*c*) the degree of combustion increased with furnace temperature.

With a view to anticipating the behaviour of various coals in dry bottom pulverised fuel furnaces, work is proceeding at the B.C.U.R.A. with two small scale pulverised coal furnaces (5 lb./hr. and 50 lb./hr). It is hoped with these furnaces to provide data indicating the likely behaviour in service in water tube boilers of coals having varying sulphur and chlorine contents. In the smaller furnace, deposits are collected on air-cooled tubes. It is recognised that perfect model systems cannot be built, and with the 5 lb./hr. model, while the residence time of the coal particles, and the flame and combustion chamber exit temperatures, are of the same order as

those in large scale plant, the gas velocities are much lower.

The IJmuiden Trials

What has become known as the IJmuiden approach is a compromise between tests undertaken with (*a*) full-scale industrial appliances—not an easy problem owing to the difficulties of securing uniform conditions as well as the expense of the instrumentation involved—and those employing (*b*) small models where conditions are not entirely representative of industrial practice, particularly so when it is not possible to simulate at the same time the factors controlling both combustion and heat transfer.

It may here be emphasised that the complete project does not merely embrace tests using an isolated furnace alone ; for the furnace tests are themselves backed by work with cold models, as well as by theoretical studies undertaken by the staff at IJmuiden. All this work is supported further by the advice and help of many experts from a number of research organisations, universities, etc., located in the different countries represented on the various committees controlling the investigation as a whole.

As Professor G. M. Ribaud told us here in his Presidential Address at the Inauguration of the new Experimental Station in April, 1954, the original project resulting in the two experimental furnaces now in operation was the outcome of a collaboration started in 1949 between Dutch, French and British organisations, all of which had been interested in the problems of heat liberation from flames. For example, earlier work by the B.C.U.R.A., in conjunction with open-hearth furnace users in Great Britain, had shown the need for careful investigations on a large scale ; and it became obvious that only by pooling the resources in manpower, experience and finance then available in the separate countries interested, could this problem be satisfactorily approached. The first full scale trials actually started in December, 1949, with an experimental furnace constructed by the Royal Netherlands Steel Works ; and representatives of the U.S.A. and Belgium soon afterwards co-operated in the work of the Joint Committee. Parallel investigations elsewhere, particularly in Sweden, have also been embraced in the overall project.

Coincidentally with the growth of experience and experimental precision of the test teams, the original furnace in due time not only became aged but also less suitable. All this led by April, 1954, to the construction of a new furnace—that now in operation for studying the behaviour of oil and gas flames. Beside this has grown another new furnace for setting pulverised fuel flames, and this is the subject of today's inauguration.

Oil and Gas Firing

The tests using oil and gas flames undertaken over the last six years have provided a wealth of experimental data. Indeed, one of the principal difficulties experienced has been to present the results in a form assimilable by the designers and users of combustion appliances. Naturally, time will not now allow a detailed description of all the results obtained but it may be of interest to direct attention to some of the more salient features.

A main outcome of the work would seem to be evidence for the prediction that the rate of mixing of the gaseous or liquid fuel with the combustion air is the predominant factor controlling the rate of combustion and subsequent heat release. The rate of mixing is controlled by the momentum imparted at the burner ; increased momentum gives rise to a shorter, hotter flame.

As is well known, the radiation from a flame is a function both of temperature and of the emissivity of the gases and solid particles therein. For this reason, when heavy fuel oil and pitch creosote are employed as combustibles, the flames give emissivities approaching unity due to the presence of solid particles, and thus radiate nearly four times as much heat as, say, flames using coke oven gas at the same attained temperature. Methods of increasing the emissivity of flames were, therefore, pursued and, while it was found on the one hand that the radiation from a coke oven gas flame enriched by up to 15% of fuel oil, increased proportionally with the amount of oil added, it was shown on the other hand that, with heavy fuel oil and pitch creosote flames, about 20% and 30% of these fuels, respectively, could be replaced in flames of the same size as those in the IJmuiden furnace by coke oven gas without any loss in emissivity of the resultant flames.

These and other results suggest that, first, a significant increase in the emissivity of flames of low luminosity is more difficult to obtain than the necessary temperature rise to give the same additional heat flow ; and second, with highly luminous flames of industrial dimensions, it is equally difficult to cause an appreciable drop in the overall emissivity. Hence, for example, it is often possible by, say, increasing the burner momentum, to get a hotter luminous flame without impairing its emissivity characteristics.

The above observations, however, cannot be considered by themselves in their bearing on furnace practice. Non-luminous flames are usually hotter than more luminous flames, and the interplay of the influences of temperature and emissivity is such as to make it apparent that, whether systems exhibit high or low emissivity, high combustion rates—the actual rates of total heat liberation in the furnace—provide a factor of dominant importance. This is particularly so when account is taken of re-radiation, gas recirculation and convective heat flow.

It has become increasingly evident that gas recirculation is a very crucial factor affecting the ignition, combustion and emission from the flames. Further study of it is obviously needed.

The question of re-radiation is most important. Transfer of heat, of course, can never depend entirely on the direct transfer of radiant energy from the flames within a furnace to the desired receptor, whether furnace walls or a charge. Some of it is re-radiated from the furnace walls, and the amount received at any one locus is, in fact, transmitted by devious routes.

As already implied, one of the factors leading in practice to increased heat transfer with higher momentum flames is convection. With the IJmuiden furnace, heat transfer by convection to the walls may be regarded as small because the flames do not actually impinge upon them. In melting practice, however, the flames are usually directed somewhat on to the stock being heated. In this connection a preliminary investigation was undertaken earlier this year into the importance of convection, the results showing that—in respect of temperatures up to 1,500° C.—a normal type of non-dimensional equation can be used to relate heat transfer with Reynolds number. The contribution of convection to the total

heat exchange in a furnace may, therefore, become calculable.

In another direction, the installation this year of a preheater has enabled a series of trials to be conducted with the combustion air preheated to temperatures up to 700° C. The broad conclusion from the experiments so far completed is that air-preheat exerts no observable influence on the emissivity of the flames studied; preheat of the fuels themselves may, however, exert significant effects.

Various methods are being developed to enable the effect of such factors as these to be allowed for in adapting the experimental results obtained under somewhat idealised conditions at IJmuiden and elsewhere to conditions in actual furnaces. It is hoped that the simplified mathematical " step-by-step " model primarily based on radiation theory and being developed by Professor Thring will be of great value in this connection; mention should also be made of the broad experimental approaches of Professor R. J. Sarjant at the University of Sheffield, and others.

Passing reference may perhaps also be made here to the discussions which have followed observations on the influence of variation in the steam/oil ratio. The work at IJmuiden has indicated that an increase in steam/oil ratio, associated with an increase in momentum, leads to decreased emissivity, with consequent fall in radiant flux from the flames. On the other hand, a melting-shop manager will tell us that an increase in steam/oil ratio increases the melting rate. When, however, an overall picture—involving, as it does, considerations of the rate of heat release and re-radiation effects—is taken into account, the separate observations are doubtless not incompatible. Indeed, the clarification of ideas resultant upon sorting out such aspects of the work has been profitable, and it is by these discussions that the IJmuiden work can assist the thinking of scientist and technician alike.

Finally, mention should be made of the " Combustion Mechanism Trials " in which detailed investigations have been undertaken into the influence of input variables on the development of combustion and the formation in flames of the carbon particles giving rise to luminous radiation.

Pulverised Fuel Firing

The investigation into oil and gas firing already outlined have directed attention to a number of factors controlling efficient heat release in furnaces, and not least to the importance of mixing rate; in this connection, experiments using cold model mixing techniques have played a valuable contributory part. The problems associated with pulverised fuel firing, however, are more complicated and perhaps more interesting; for, in addition to those common to the use of liquid and gaseous fuels, the rate of heat release is doubtless also dependent upon such factors as coal fineness, coal type and volatile matter, the content and nature of mineral matter, etc., and the prospective programme with pulverised fuel has been planned to take account of these additional factors.

In industrial practice pulverised fuel is burned under a variety of conditions but predominantly for two main purposes, namely steam-raising in water-tube boilers and the manufacture of cement. For use in water-tube boilers, pulverised coal and its primary combustion air are injected into the furnace surrounded by secondary air; the flame is maintained in a chamber, the walls of which are today generally water-cooled. In the cement industry, the pulverised coal and the air for combustion are injected into a furnace with hot walls, and normally the air pre-heat is greater, and the amount of excess air lower, than in boiler firing. It is one purpose of the work at IJmuiden to endeavour to explore this wide range of variables at the disposal of operators of pulverised fuel appliances; and, while emphasis will be placed on the range of conditions relevant to the two major processes referred to, the programme is not intended to be in any way restricted to them if scope for wider developments should emerge.

To sum up, the objectives of the programme on pulverised fuel combustion at IJmuiden can be divided into four categories. From a theoretical standpoint, it is hoped (*a*) to secure or substantiate information which will assist a better understanding of the principles controlling the combustion and heat release from pulverised fuel, and thereby to furnish data of value to those concerned with design of pulverised fuel appliances. In effecting this, it should be possible (*b*) to take advantage of, and extend, the knowledge described in the first part of this paper and concerned with the chemical reactions and rate-determining processes in solid fuel combustion, particularly in connection with fuel particles in suspension. It is also hoped (*c*) that the operational engineer or designer will be better able to predict the effect of changes in operating conditions. Another objective of the work (*d*) is to develop instruments and techniques; for while it has already been found that the instruments developed at IJmuiden are applicable to industrial plant, it is anticipated that the work which has still to be done on the grinding and sizing of fuel, the examination of particles in pulverised fuel flames, etc., will lead to similar developments.

In conclusion, the value of the international collaboration, which is such a strong feature of this work at IJmuiden, cannot be over-emphasised; the interchange of viewpoints and experience between specialist technical personnel in one country and in another cannot but enable ideas to be formulated more quickly, and it must also help to encourage good international relations, particularly in a field of vital importance to us all, namely fuel technology.

Presentation to Mr. J. H. Bean

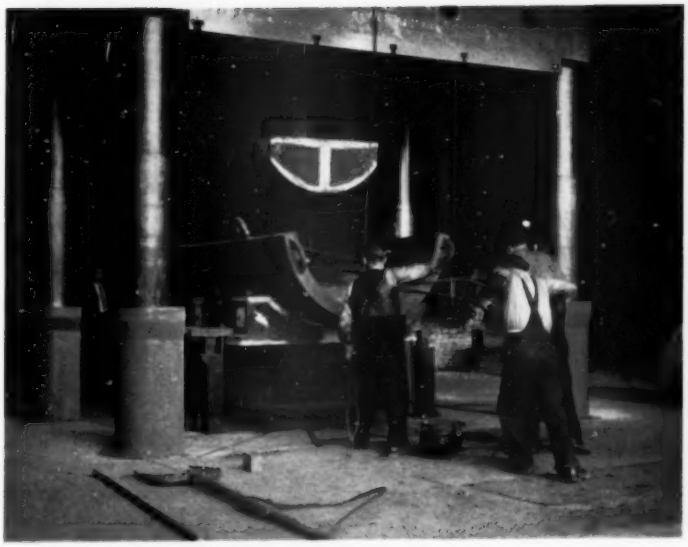
At a Reception and Dinner at the Queens Hotel, Birmingham, on Friday, November 4th, Mr. J. H. Bean, C.B.E., who was Chairman of Garringtons, Ltd., from 1939 until his retirement in June of this year, and whose period of office was associated with tremendous growth in the Company's affairs, was presented by his Garringtons colleagues with a gold Rolex Oyster perpetual chronometer watch. Mr. Bean, who helped to build many Midland industrial undertakings, continues as Chairman of Beans Industries, Ltd., Midland Industries, Ltd., and B.R.D., Ltd.

Wickman Representation Changes

Wickman, Ltd., have established a new area office in Nottingham under the control of Mr. E. J. Swinn. The address of the new office is 36, Market Street, Nottingham (Tel.: 43850). In the Glasgow area, Mr. G. Archibald, who has for many years been a technical representative for the Company, has now been appointed Acting Area Manager in succession to Mr. J. Macgregor.

Pressing the Ends of Steam Drums

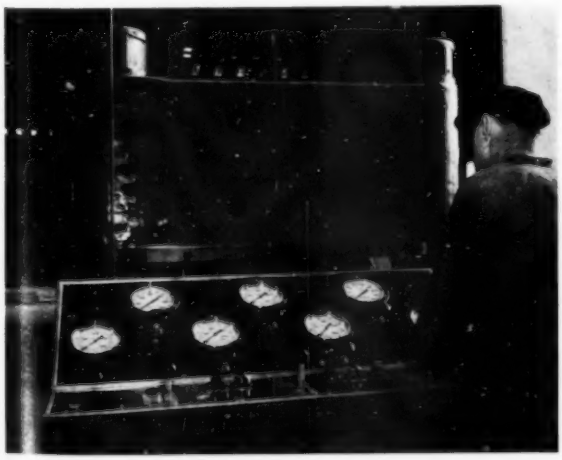
New 2,000 ton Press for Babcock & Wilcox Ltd.



View showing upper bolster raised and lower die with workpiece in the operating position.

A NEW 2,000 ton, 4 column press has recently been installed at the Renfrew Works of Babcock & Wilcox, Ltd., to assist in the production of boiler drums. Up to now the ends of the steam drums have been pressed in the Forge Department and machined in the main machine shop. The largest press hitherto available for this particular work has been one of 480 tons, which has involved multi-stage pressing operations for the thicker plates. The new press will enable drum ends of any size so far envisaged to be easily handled, and should be of considerable assistance to the future programme in atomic power plant. The press, together with a bogie type furnace, is located in the Forge Department, and vertical boring mills for machining the pressings are located in an adjacent bay.

When this new press was first contemplated, it was realised that if a conventional design were used it would require a very much larger building than the present forge. This would mean that the existing crane could not be used over the entire length of the shop and, in addition to the extra building height, would have necessitated a second crane which would, of course, have been restricted to the immediate area of the press.



View from control table from which all operations of the press and sliding table are controlled by servo-operated valves.

To keep the head room down, the press is of the moving-column type which, in effect, gives an inverted arrangement. The lower die, instead of being raised on a ram, is located on a fixed table at floor level, and the moving die is attached to the upper bolster, to which are attached the main columns of the press. These pass through the table and are attached at their lower ends to a second heavy steel bolster, upon which the hydraulic cylinders act. All this part, of course, is below floor level. In order to accommodate a press of this type a very deep foundation pit had to be provided and, although the overall height of the press above the shop floor is only 18 ft. 9 in., the foundation pit is some 40 ft. deep and very nearly the same in diameter.

Since the water table in this area lies between 15 and 20 ft. below the surface, the sinking of a foundation pit of this type proved a major problem in civil engineering. This work was carried out by Balfour Beatty & Co. Ltd., and involved the use of a diver for about half the depth of the excavation and the placing of the concrete plug at the bottom. This plug alone amounted to some 450 cu. yd. of concrete which. like all the concrete used on the job, was supplied by Jaeger System Concrete, Ltd., in ready-mixed batches. This company, incidentally, gave a 40-hour continuous service at one stage of the work. Some idea of the magnitude of the complete task may be gathered from the quantities involved, which included the excavation of more than 3,000 cu. yd. of earth and the supply of 1,500 cu. yd. of concrete. Some 3,800 sq. ft. of Larssen sheet steel piling and 11 tons of steel reinforcement were used.

The press itself was designed and built by Fielding & Platt, Ltd., and some idea of its dimensions may be gathered from the accompanying table and the capacity.

It will take the heaviest plate rolled, with a maximum width of 12 ft. 6 in., and it is suitable for pressing drum ends from 12 ft. 6 in. circular blanks 7 in. thick. The pressure is applied by two main rams and four auxiliary rams arranged in a square, with two draw-back rams to raise the moving portion. For feeding work in and out, there is a sliding table operated by two hydraulic cylinders with a stroke of 12 ft. 6 in. and a combined power of 50 tons.

The entire control of the press and sliding table is from a desk type control panel adjacent to the press, the main hydraulic valves being servo-operated. The power supply for the press is taken from the existing hydraulic mains operating at 1 ton/sq. in. The press is associated with an oil-fired furnace supplied by the Dowson and Mason Gas Plant Co., Ltd., for plate heating service: it is proposed to install an additional furnace at a later date.

Details of the Press

Total power, with all rams in operation	2,000 tons
Two outside rams	1,334 tons
Centre rams only	667 tons
Stroke of moving press head	8 ft. 0 in.
Maximum daylight of press	11 ft. 6 in.
Minimum daylight of press	3 ft. 6 in.
Column centres: Left to right	14 ft. 6 in.
Front to back	10 ft. 3 in.
Bolster slide plate dimensions	13 ft. 9 in. × 12 ft. 6 in.
Approximate overall height of press above floor level	18 ft. 9 in.

Combination Rolling Mill

Small Two-High/Four-High Units

THE user of a two-high strip mill at times comes up against the difficulty that his completely screwed-down mill is unable to produce further gauge reductions. In the past one solution has been to continue processing the strip on a four-high or cluster mill having considerably smaller work rolls backed up by large supporting rolls. Now a versatile two-high/four-high combination mill, developed particularly to overcome this problem, has been designed in the United States and is being manufactured under licence by a British firm. The equipment, known as the Stanat-Mann two-high/four-high Combination Rolling Mill, is at present available in the 1½ in. and 5 in. × 8 in., and the 2¼ in. and 8 in. × 8 in. sizes.

Designed to accomplish the work of two or more mills, this new heavy duty machine can be used for bar, rod and strip reduction. The motor and drive are completely enclosed in the base, presenting an unusually clean appearance. In one compact machine, the mill performs the following functions: (*a*) hot flat rolling; (*b*) cold flat breakdown; (*c*) cold flat finishing on either a two-high or four-high set up; and (*d*) hot or cold rolling of wires and shapes. To make the change from two-high to four-high, the large rolls are separated and two smaller work rolls are inserted between the large ones, which then become back-up rolls.

When functioning as a conventional two-high unit, the relatively large work roll diameter of the mill is

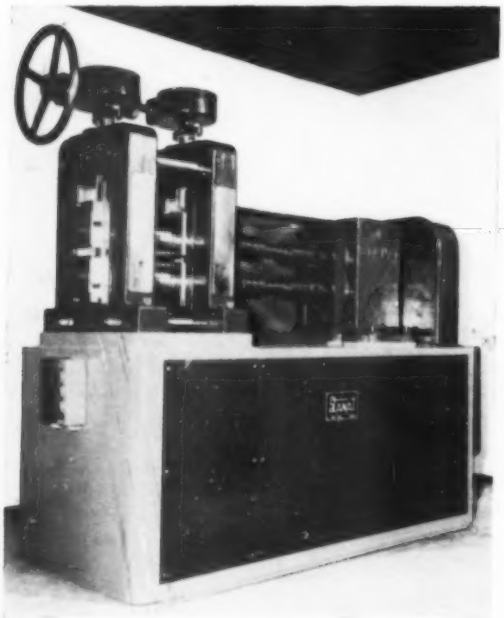


Fig. 1.—Two-high arrangement of combination mill with grooved rolls installed.

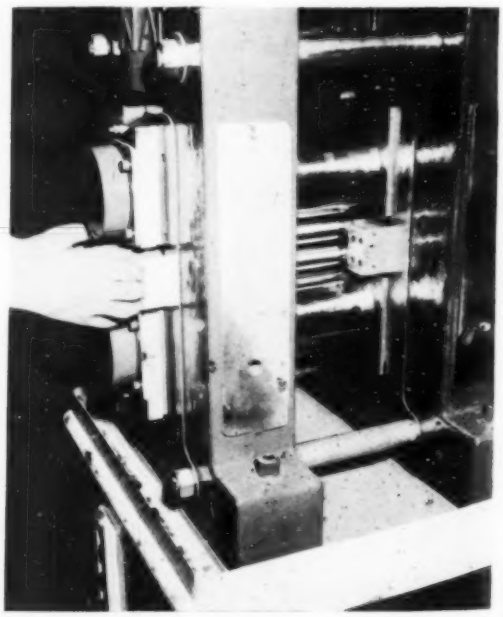


Fig. 2.—Changeover from two-high to four-high arrangement is made by inserting work roll assembly.

valuable for the break-down of ingots and bars, the reduction of high lustre strip, and for the skin-passing of annealed strip. Because a larger work roll diameter causes greater slipping between the roll surface and the material, bright and highly burnished surface finishes can be obtained when reducing annealed strip. An added advantage of the larger work roll diameter is its greater circumference, which reduces wear, thus improving performance and lengthening work life between grindings.

In flat rolling, the prime advantage of the four-high set-up is that with a given roll load capacity and mill horsepower, greater reductions may be taken with the smaller diameter work rolls. Furthermore, in rolling the harder metals and alloys, the smaller work roll reduces the lateral spread, and hence the tendency of the strip edges to tear or crack. The " stiffness " of the backed-up four-high mill, and the ease with which its small work rolls can be " crowned," makes possible the production of extremely accurate strip having practically no thickness variation across its width. The smaller work roll facilitates thinner strip finishing gauges, even in highly work-hardened materials, since the length of the flattened arc of contact between the work rolls and the material decreases with the decrease in work roll diameter. The roll loads and rolling torques can be reduced even further by employing solid tungsten carbide work rolls.

Depending on the required range and speeds of reduction, the two-high/four-high combination mill can be powered by a constant-speed or a four-speed gear-shift A.C. drive, or a variable-speed D.C. drive. The mill motor is mounted in the unit base of the machine and drives the pinion stand through double-helical reduction gearing. The pinions drive the two large-diameter rolls through silent universal spindles.

In this "all-purpose " mill, the back-up drive employed eliminates one of the most serious disadvantages of the conventional four-high mill—the limitation in torque that can be transmitted by the relatively small roll necks and spindles. Another valuable feature of the back-up drive is its ability to overcome the lateral " bowing out " of the small work rolls when taking heavy reductions with high front tension.

The method of providing front and back strip tension can be varied in accordance with maximum strip pull requirements and coil build-up ratios. In the simplest arrangement on a non-reversing mill, back tension is applied by a friction brake on the pay-off reel, and variable front tension is obtained by driving the coiling reel from the main mill motor through an adjustable slip clutch. Reversing mills can be equipped with a variable-voltage D.C. drive, facilitating very precise tension control. The improved reductions and strip flatness obtainable with the application of front and back tensions permits the successful cold-working of thin hard metals.

To accommodate heavy separating loads, the housings of the mill are high-strength castings mounted on a unit base of fabricated steel plate construction. The housing posts are designed with exceptionally large cross-sectional areas to obtain the extreme rigidity necessary for handling severe roll loads. Anti-friction roll neck bearings are used on the back-up and work rolls and have provision for taking both radial loads and end thrust.

Both flat and grooved rolls are available for the processing of round, square and other shapes. Hot rolling can be performed over a roll temperature range up to 1,000° F. For heat dispersion in hot rolling, the mill can be equipped with a self-contained bearing lubricant circulating, cooling and filtering system, and with means of circulating water through the roll interior.

Stanat-Mann two-high/four-high combination rolling mills are made by Albert Mann's Engineering Co. Ltd., of Basildon Industrial Estate, Essex.

Mechanical Sieving of Columbite

New Technique Overcomes Choking of Screens

WHEN mining operations are carried out with a view to winning a particular metal, it sometimes happens that large quantities of other material have to be excavated in order to obtain a small amount of the sought-for product. In the mining of gold for instance, as much as a ton of material may produce only a quarter of an ounce troy of pure gold after processing. Unwanted material is usually disposed of by piling it up on the site of the workings. These miniature mountains do not improve the landscape and are a constant source of annoyance to the mine owners owing to the large area of valuable land that is then rendered unproductive. There is one notable exception to this, however ; it is a fact that wherever deposits of tin occur, so also do those of many other valuable ores, and in some districts one of these is columbite. Columbite is a niobate of iron and manganese and is the largest source of columbium (niobium), which is all-important in the manufacture of electric light filaments, jet engine components and certain atomic equipment. It is worth about £2,000 per ton.

Although it had long been known that the dumps of refuse material on some tin mining sites contained large quantities of columbite, no means could be found to separate it at a profitable rate, in spite of the fabulously high price that could be obtained for the ore. Great interest was, therefore, evoked recently when a machine was introduced, by means of which almost any predetermined metallic ore could be separated from associated material. Unfortunately this new separator could only treat material which had been reduced to a powder consisting of particles of like sizes. At first glance this would appear to offer no real difficulty, since the process of sieving usually constitutes a ready means of sizing out particulate matter. However, no existing sieving machine could deal effectively with powdered columbite, the difficulties being associated with the curious form of the columbite particles, which are mostly shaped like minute carrots.

As is well known, a sieving machine usually takes the form of a rectangular tray dressed with a suitable wire mesh or screen, and this assembly is caused to vibrate either backwards and forwards or else up and down at a high speed. This causes the particles of the powder to bounce about upon the mesh surface. Thus, the particles

that are small enough will pass through the mesh, and under ordinary circumstances those that are too large to pass the mesh apertures will continue to bounce over the screen until they pass off via the reject outlet. In the case of columbite, however, the minute carrot-shaped particles tend to enter the screen apertures pointed end first, and other bouncing particles hammer them firmly home, with the result that the screen is very quickly choked, and the whole assembly has to be dismantled and cleaned before further operation is possible. Indeed, many mine operators have preferred to resort to the expensive and laborious process of hand sieving rather than face the difficulties and delays involved in any attempt to perform this process by mechanical means.

Recently the problem of the mechanised sieving of columbite has been tackled from an entirely new angle. One of the leading tin mine owners of Nigeria in West Africa approached the firm of Russell Constructions, Ltd.—a firm who have had much experience in sieving and straining technique (most particularly during the recent war when the mass production of explosives involved the high speed sieving of many dangerous and sensitive compounds). It was indeed a machine that had originally been designed by Messrs. Russell for the sieving of tracer bullet powder that was adapted to the classifying of columbite.

It should be explained that in this ingenious unit the vibrations which promote the sieving effect are of a gyratory nature; that is to say, the mesh screen is caused to move in a minute circular orbit (this motion usually has an amplitude of about $\frac{3}{16}$ in.) and at the relatively high speed of 1,500 cycles per minute. This movement takes place in a strictly horizontal plane, and has the effect of generating in any particulate matter placed upon the screen an entirely unique type of motion.

When applied to columbite, the carrot-shaped particles are imbued with a dual motion. They rotate on their longitudinal axes and, at the same time, turn end over end, but all the while all bouncing movement is strictly eliminated. Special instruments made it possible to observe the impact of this effect at the mesh surface during the operation of the machine, when it was shown that the spinning motion helped the carrot shaped particles to pass readily through the screen apertures, while the end over end movement rendered it impossible for any material to stick in the mesh and cause blinding.

Centrally located is the circular housing which contains the flywheel that generates the gyratory movement. A $\frac{3}{4}$ h.p. electric motor supplies the power. The screening assembly is mounted in compressed rubber bushes, and takes the form of Russell's well-known Cascade unit. In this there are three circular screens superimposed one above the other, the whole assembly being housed in a dust tight casing measuring 22 in. in diameter and 11 in. in height. The mesh discs are 19 in. in diameter and have a combined total area of $6\frac{1}{2}$ sq. ft.

The columbite powder is introduced at the top of the unit and the gyratory motion causes the material to take a spiral path passing successively over the three discs. The fine particles which pass through the mesh apertures travel down the central duct of the machine and issue from the spout on the right of the unit, while the oversize material which passes over the edge of the discs is collected and passed off via the reject outlet spout on the left of the unit.

In practice these machines have proved to be a great success. A very accurate and thorough separation of the sized particles takes place, and such troubles as accrue from clogging and blinding of the mesh are entirely absent. Moreover, the machine calls for the very minimum of maintenance and even complete remeshing of the screens can be carried out by unskilled labour.

Secondary Aluminium Production at Elswick

As with other metals it has long been recognised that the re-use of scrap aluminium and its alloys has an important economic value in supplementing the supply of virgin aluminium, and by care in sorting, melting, and refining scrap, billets can be produced that meet required standards and compare favourably with those produced from virgin metal. Many firms are now engaged in the successful production of this secondary aluminium, and Associated Lead Manufacturers, Ltd., is probably the more recent one to enter this field with the plant in operation at their Elswick Works, Newcastle-upon-Tyne.

In connection with the smelting and refining of lead, which is the primary activity at these works, a competently staffed laboratory was already functioning, and it was comparatively easy to equip a department to accommodate facilities for the melting and refining of scrap aluminium for conversion into serviceable billets. This department has been successfully operating for a few years and is meeting a need, particularly in the North-East area.

Three gas-fired furnaces are installed for melting the scrap, one a large reverberatory furnace in which scrap containing other metals is melted. In this furnace the aluminium flows to the hearth as it becomes molten, and other metals of higher fusion temperature are withdrawn prior to the next charge of scrap. The fluid aluminium is run into billet moulds and the billets are generally remelted in one of the two rotary furnaces of similar capacity.

Considerable care is exercised in the sorting of the scrap according to composition to minimise the need for refining, and much of it is melted directly in the rotary furnaces. The grades of alloy billets produced cover the normal range, from the relatively low grade billet used as a deoxidiser in the manufacture of steel to the higher grades of A.I.D. standard. The works are conveniently situated for transport, either by river, rail or road.

Change of Address

THE Manchester Office of The United Steel Cos., Ltd., has removed to larger premises. The new address is: National Building, St. Mary's Parsonage, Manchester, 3. The telephone number remains unchanged: Blackfriars 3526. Mr. H. A. Wilkinson is manager of the Manchester Office, which is responsible for the company's sales in Lancashire, Cheshire, North Wales and part of Staffordshire.

The London office of The Loewy Engineering Co., Ltd., is now at 1, Albemarle Street, London, W.1. (Tel.: HYDe Park 9959; Telegraphic Address: "Loewyworks, London).

Father of Metallurgy and Mineralogy

A Tribute to Agricola on the 400th Anniversary of His Death

By M. Schofield, M.A., B.Sc., F.R.I.C.

ALTHOUGH there have been Roman generals, German musicians, writers and scholars all known by the name of "Agricola," none could claim to have made greater contributions to progress than Georgius Agricola, father of metal extraction processes, who died 400 years ago. Agricola's name was really Georg Bauer, a name latinized according to the practice of the times, and one which has survived the centuries. The anniversary of his death is an occasion to look back with no little astonishment at all he did for metallurgy in those early years, particularly the contributions occupying the twelve volumes of his classic *De Re Metallica*.

Medicine to Metallurgy

Agricola might well have gone permanently into medicine or to an academic career, instead of becoming one of the many doctors who crossed the border from one science to another with lasting benefits to the new field. He studied chemistry, physics, and medicine at Leipzig, graduating there and becoming vice-principal of a school at Zwickau for a time. He later became principal, yet this teaching of classics was only a prelude to a career to follow which education could well spare him. After going to Italy as the great centre for medicine, taking a higher degree there and writing his first scientific work—a critical revision of Galen's classic—Agricola became a physician, first at Zwickau, and then at that town so famous for mining that this subsequent change of career seems less surprising than it would otherwise have done. The mining centre of Joachimsthal inspired Agricola to take up metallurgy long before it achieved fame as the source of pitchblende from which the Curies won radium. It was there that the physician began his first studies of metallurgical processes and mining, and there, too, that he wrote an early book called *Bermannus*. This was written in general terms, a book which Erasmus encouraged him to write, and one in which, for example, we read of "fluores," or fluorspar, "made use of when metals are smelted, as it causes the material in the fire to be much more fluid." About this time Agricola had become historiographer to the Prince of Saxony, and had shown interests outside medicine by writing a second work, a treatise *De Mensuris et Ponderibus* dealing with weights and measures.

Moving to Chemnitz as city physician, Agricola also became burgomaster, a post which, fortunately for metallurgy, he had to resign as a Roman Catholic. So his leisure hours became devoted to writing and studying metallurgical matters, culminating in that classic for all time, his *De Re Metallica*, published in twelve volumes or sections. At Chemnitz, Agricola had written some studies on physical geology, on subterranean waters and gases and on mineralogy. But these were but opening chapters, just as the marble memorial plaque in Chemnitz museum is an insignificant memento compared with Agricola's twelve-volume work.

"De Re Metallica"

In a preface, Agricola set out his intentions: how he would describe the founding of veins with stringers and seams in the rocks; the functioning of mining officials and surveyors; and the digging of ores. He dealt with mining equipment and machines, with assaying, with roasting, with crushing and washing of ores, and then with their smelting. He wrote of muffles, bellows, crucibles, cupels and fluxes. Individual topics included the separation of silver from gold, and of silver from lead and copper. Gold and silver assaying were known to the alchemists, of course, before Agricola's great work appeared; yet the authentic assaying of lead, tin, copper, mercury, iron and bismuth all came from the work of this versatile man. He wrote of antimony as "stibium," which, he maintained, "when smelted in the crucible and refined, has as much right to be regarded as a proper metal as this term is accorded to lead by writers. If, when smelted, a portion be added to tin, a bookseller's alloy is produced from which the type is made that is used by those who print books on paper." The metal bismuth was recognized as a specific metal by Agricola long before miners believed it to be a form of lead. Miners clung to the old beliefs up to the eighteenth century, considering lead, tin, and bismuth simply three stages in the transformation to silver; hence their regret on striking bismuth ore: "Alas, we have come too soon!" Yet the true facts should have been known, since Agricola gave reduction processes for winning bismuth by use of charcoal. His name also crops up in zinc history, since he referred to "zincum" from furnaces in Silesia. Although Agricola's twelfth book or section included details or rules for the manufacture of salt, soda, "allum," vitriol, sulphur, glass and bitumen, chemistry was still an unborn science. Just 200 years ago, that is two centuries after the death of Agricola, Joseph Black wrote his dissertation on Magnesia Alba, in which alkalies were first differentiated even from elements, for elements they were according to the chemistry from Boyle's time. Yet here was Agricola contributing so much authentic matter before chemistry revealed the basis of metal extractions—contributions in such contrast to the ignorance and superstitions of the medieval past.

Stainless Strip Plant Order

THE Wellman Smith Owen Engineering Corporation, Ltd., have recently received orders for stainless steel strip processing and pickling lines to the value of approximately £900,000, including a £200,000 contract for Sweden secured against German, Austrian and Swedish competition.

NEWS AND ANNOUNCEMENTS

Conference on Lubrication and Wear

THE Council of the Institution of Mechanical Engineers are arranging a Conference on Lubrication and Wear to be held from Monday, October 1st, to Wednesday October 3rd., 1957, inclusive. Meetings for the presentation of papers will be held each day, as much time as possible being allowed for discussion. It is hoped to obtain papers covering the whole field of lubrication and wear.

The general principles adopted by the Council in planning the technical sessions are that there should be some papers that will collate and summarise well-established aspects of the subject and, where possible, enlarge on them, and other papers will be devoted to particular topics that are rapidly developing, thus giving a special character to the Conference. The Council agreed that the subject of wear would be an appropriate specialised subject.

The Council desire that the published Proceedings of the Conference shall constitute a useful reference work, and to this end they will ensure that careful discrimination is shown in the choice of subject-matter. They invite both members and non-members of the Institution to contribute papers to the Conference. Each contribution will be treated on its merits, but the Council wish to emphasise that, even if a paper is accepted in principle as regards the subject covered, it may have to be modified after initial drafting to fit into the general framework of the Conference. In order to avoid unnecessary work, therefore, intending authors are invited to submit, in the first instance, a brief synopsis of, say 200 words, setting out the proposed title and contents of their contributions. These should be received by the Secretary of the Institution at the latest by April 1st, 1956, but notification before this date of intention to submit a synopsis would be very helpful. The Council will then be able to review the contributions in the light of the number received and the fields covered by them. The Council will furnish every assistance to those authors invited to write papers as a result of consideration of the synopsis submitted by them. It is likely that the final manuscripts will be limited to a maximum length of 3,000 words. Illustrations will be permitted. Further information may be obtained on request from the Secretary of the Institution of Mechanical Engineers, 1, Birdcage Walk, London, S.W.1.

Institute of Metals

Nuclear Energy Committee Formed

THE Council of the Institute of Metals has appointed a Nuclear Energy Committee, with the object of stimulating interest in metallurgical problems arising in connection with the industrial and scientific aspects of the use of nuclear energy. It is proposed that, among its activities, the new Committee shall arrange special meetings, discussions and symposia; invite the writing of papers or articles for publication; and arrange the publication of books or other literature to attain the objects for which it was formed. The Committee hopes to arrange an exhibition of nuclear energy products, of interest to metallurgists, in connection with the Institute's Spring Meeting in April, 1956.

The constitution of the Committee is: MR. G. L. BAILEY (British Non-Ferrous Metals Research Association); MR. E. W. COLBECK (Hadfields, Ltd.); DR. MAURICE COOK (Imperial Chemical Industries, Ltd., Metals Division); DR. S. F. DOREY (Lloyds' Register of Shipping); DR. H. M. FINNISTON (United Kingdom Atomic Energy Authority); DR. IVOR JENKINS (The General Electric Co., Ltd.); PROFESSOR A. G. QUARRELL (University of Sheffield); MR. L. ROTHERHAM (United Kingdom Atomic Energy Authority); MR. S. S. SMITH (Imperial Chemical Industries, Ltd., Metals Division); and MAJOR P. L. TEED (Vickers-Armstrongs (Aircraft), Ltd.).

Persons interested in the activities of the Committee should communicate with Lieut.-Colonel S. C. Guillan, Secretary, The Institute of Metals, 4, Grosvenor Gardens, London, S.W.1.

1956 Mechanical Handling Exhibition

THE next Mechanical Handling Exhibition and Convention at Earls Court, London, from 9th to 19th May, 1956, is expected to be the largest and most comprehensive display of labour-aiding equipment ever seen. With upwards of 250 exhibitors, occupying more than 400,000 sq. ft. of floor space, the entire display has been most carefully planned with numerous exhibits in operation and a special demonstration area where the larger and more mobile types of equipment will be seen handling various commodities and materials. The Convention, which will run concurrently with the Exhibition, will be international in character, and overseas speakers will discuss in open forum their methods throughout a wide range of industries. A full programme of industrial films is also being arranged.

Conference on Properties of Materials at High Rates of Strain

THE Council of the Institution of Mechanical Engineers, in collaboration with its Applied Mechanics Group Committee, is taking steps to organise a Conference on the Properties of Materials at High Rates of Strain, to take place in London in March, 1957. The materials under consideration in this conference will include only those used in the manufacture of mechanical engineering structures or elements and will exclude fluids. The conference will largely take the form of the presentation and discussion of a series of papers and arrangements will be made to issue copies of these in advance. The meeting will probably last from two to three days. It is expected that the papers will be grouped under six main subject headings as follows:—(*a*) Metal Physics; (*b*) Experimental Techniques; (*c*) Wave Propagation Strain-Rate Effects on Small Strains; (*d*) Metal Working; (*e*) Non-Metals; and (*f*) Basic Properties.

The Council is ready to consider the publication of manuscripts submitted in connection with this proposed conference. So as to allow sufficient time for the refereeing of manuscripts, the latest date for submission to the Secretary, will be the 30th September, 1956, but authors should notify the secretary as early as possible

of their intention to submit a paper, and the finished manuscript should be submitted without delay.

Full details of the arrangements for the conference will be published in due course.

1956 Machine Tool Exhibition

AFTER an interval of four years, the International Machine Tool Exhibition, organised by the Machine Tool Trades' Association, will be held at Olympia from 22nd June to 6th July, 1956. Exhibits will include metal working machine tools and woodworking machinery, engineers' small tools, gauges and measuring equipment, testing equipment, presses and power hammers, and heat treatment plant. Apart from the United Kingdom, exhibits will be seen from leading machine tool manufacturing countries including Belgium, France, Germany, Holland, Italy, the Scandinavian countries, Switzerland and the United States.

Lecture Course on Inspection and Testing of Metals

A COURSE of Lectures on the " Inspection and Testing of Metals " will be held in the Department of Metallurgy, Battersea Polytechnic, on successive Tuesdays, at 7 p.m., commencing January 10th, 1956. The topics covered will include the basic principles and procedures for inspection ; inspection of non-ferrous materials ; inspection of ferrous materials ; control and testing applied to electrodeposition and other protective treatments ; modern methods of routine analysis ; mechanical testing of metals ; non-destructive testing ; quality control by statistical methods ; fatigue testing ; investigations of failures and defects ; and precise measurement for engineers. The fee for the course is £1, and applications should be sent with the fee to the Secretary (I/T of Metals Course), Battersea Polytechnic, Battersea Park Road, London, S.W.11, showing the name and address in block capitals, occupation, and name and address of employer. If the applicant has previously attended this Polytechnic, the year and course attended should also be given.

Increasing Productivity by Welding

THE London Meeting of the series on " Increasing Productivity by Welding " will be held at the Institution of Electrical Engineers, Savoy Place, London, W.1 on Thursday, January 12th, and Friday, January 13th, 1956. It is one of a series of two-day meetings arranged by the British Welding Research Association at which recent developments in welding and design technique are considered.

New Instrument Company

THE West Instrument Corporation of Chicago, formed in 1946 by an ex-naval air service pilot, Commander R. K. West, who graduated from Massachusetts Institute of Technology in 1938, has steadily expanded its production and has acquired a leading position as a source of electro-mechanical control and measuring instruments and automatic industrial control equipment for the process and plastics industries. A subsidiary company, West Instrument, Ltd., has now been formed in this country to supply these products to the European market and British home and overseas territories. The British company, which will manufacture the full range of precision industrial temperature control equipment, has commenced operation from 1, Newman Street, London, W.1. (Tel. : Museum 6663), whilst its new factory at Horsham is being completed.

International Conference on Fatigue

THE Council of the Institution of Mechanical Engineers is arranging an International Conference on Fatigue of Metals to be held from Monday 10th September to Friday 14th September, 1956, inclusive. It is hoped to obtain up to sixty papers covering the whole field, and these will be divided into groups, the papers in the various groups being presented for discussion in abstract form by rapporteurs. The presentation of the papers will be preceded by an address reviewing the field of knowledge of fatigue., delivered by Dr. H. J. Gough, C.B., M.B.E., F.R.S., a Past-President and Honorary Member of the Institution.

Research Work in West Midland Technical Colleges

A SURVEY conducted by the West Midlands Advisory Council for Further Education has shown the considerable volume of research work which is being undertaken in senior technical colleges in the West Midlands. About six colleges have active programmes which include research projects sponsored by government departments or individual firms. Several colleges have appointed research assistants or fellows. Some 60 original papers have been contributed to scientific journals during the last four years from college staffs. The subjects have been in the fields of chemistry, physics, mathematics, engineering and ceramics.

Exhibition Film Premiere

AT the Empire Rooms, Tottenham Court Road on Tuesday, November 15th, the Electrical Engineers Exhibition Company staged the premiere trade presentation of their sound film of the Fourth Exhibition held at Earls Court. The showing was attended by over a hundred, composed of representatives of trade journals connected with electrical engineering and old and new exhibitors. The film is already well booked to go to all the branches of the Association of Supervising Electrical Engineers, but spare copies are available at no charge for showing to industrial and educational authorities on application to the General Manager, Electrical Engineers (A.S.E.E.) Exhibition, Ltd., 23, Bloomsbury Square, London, W.C.1.

Clyde Ore Handling Plant

THE Fraser & Chalmers Engineering Works of The General Electric Co., Ltd., has received an order, valued at over £600,000, from Colvilles Ltd. for an ore handling, storage and loading plant, to be installed at General Terminus Quay in Glasgow on the River Clyde. Iron ore for the furnaces both at Colvilles' Clyde Ironworks and their new Ravenscraig Works at Motherwell will be unloaded from vessels berthed alongside the General

Terminus Quay. The plant comprises a double line of conveyors from the quayside, and storage bunkers at the adjacent rail sidings.

Each conveyor line has a capacity of 1,000 tons/hr. The quayside conveyors, each over 1,000 ft. in length, discharge to belt feeders from which further belts cross the roadway and convey for another 750 ft. to the bunkers. The storage bunkers have a total capacity of 14,000 tons and discharge ore simultaneously to four lines of 14 wagons each of 35 tons capacity. The discharge to wagons is controlled by hydraulically-operated hopper gates.

New T.I. Company in India

TUBE INVESTMENTS, LTD., announces, in conjunction with Messrs. Murugappa & Sons, of Madras, the formation of a new company, Tube Products of India, Ltd., for the manufacture, fabrication and manipulation of electric resistance welded steel tubes. The company has an initial registered capital of Rs. 20 million, and a building site of 80 acres has been acquired near Madras. Tube Products of India, Ltd., will operate in close co-operation with the T.I. home subsidiary, Tube Products, Ltd., of Oldbury, Birmingham, the pioneer company in this country in the production of E.R.W. steel tubes. It will manufacture a wide range of precision and mechanical tubes and manipulated components for the cycle and many other industries. Murugappa & Sons are already partners with Tube Investments in the company, T.I. Cycles of India, Ltd., which has for some years been producing Hercules cycles and a wide range of bicycles components for the Indian market.

G.E.C. Order for Temper Mill Drives

THE GENERAL ELECTRIC CO. LTD., has been entrusted by The Australian Iron and Steel Co., Ltd., with a contract valued at £165,000 sterling, covering the complete electrical equipment for a 2-stand temper mill for steel strip at Port Kembla, New South Wales. The mill will be similar in design to those now in commission at the Trostre Works of The Steel Company of Wales, which were the first in Great Britain to operate at strip speeds of up to 4,000 ft./min. Each stand of the mill will be driven by a 1,000 h.p. D.C. motor, and six motors totalling 2,100 h.p. are included for the auxiliary drives. G.E.C. control exciters operating in conjunction with a Ward Leonard system will be used to provide the rapid response and complete stability which are essential features of a control scheme for high-speed mills of this type. The contract is the latest of a series of orders placed with the G.E.C., for equipment for the Australian Iron and Steel Company's Works at Port Kembla; they include main and auxiliary mill motors, mercury arc rectifiers, switchboards and control gear.

Nu-Swift London Centre

THE new London showrooms and offices at 25, Piccadilly, London, W.1 of Nu-Swift, Ltd., the fire extinguisher manufacturers, have now been completed and are open. Specimens of the firm's principal products are on view and small orders urgently needed can be executed from this address. The headquarters of the firm (including the Home and Export Sales Departments and the Technical Advisory Department), continue to be located at Elland, Yorkshire.

Kanigen Chemical Nickel Plating

THE Kanigen process of chemical nickel plating will be available in 1956 in the United Kingdom. Albright & Wilson, Ltd., have signed an agreement with the General American Transportation Corporation, who developed the Kanigen process, whereby they become the sole licensees for the United Kingdom, Eire, and Denmark. Kanigen plate is an entirely new material which can be applied to metal, glass, plastics and ceramics, and provides a uniform, hard, non-porous coating on components of any shape; it is a nickel-phosphorus alloy containing about 8·5% of phosphorus.

Personal News

MR. T. G. TANNER, Technical Director of Birlec, Ltd., has been appointed Deputy Manager Director.

DR. G. L. J. BAILEY, Deputy Research Manager of the British Non-Ferrous Metals Research Association, has been appointed Superintendent of the Platinum Metals Research Laboratory of the Development and Research Department of The Mond Nickel Co., Ltd.

MR. R. J. BARRITT has been appointed Managing Director of the Metallurgical Equipment Export Co., Ltd., and its associated organisation, the Indian Steelworks Construction Co., Ltd. Mr. Barritt was formerly with Simon-Carves, Ltd., and subsequently became Carbonisation General Manager to the South West Division of the National Coal Board.

MR. E. J. BRADBURY has relinquished his appointment as Development Officer in the Development and Research Department of The Mond Nickel Co., Ltd., in London, where he has been responsible for non-ferrous wrought alloys, to take up an appointment as Assistant Superintendent of the Department's Laboratory in Birmingham.

MR. G. S. SAMWAYS has joined the Board of Sanderson Brothers & Newbould, Ltd. He was Joint Managing Director of The Metal Box Co., Ltd., until 1954, when he became associated with The Commonwealth Finance Co., Ltd.

MR. W. R. JONES has retired from the position of Midlands Area Manager of Murex Welding Processes, Ltd. Mr. Jones, who joined Alloy Welding Processes, Ltd., 29 years ago, will be succeeded by MR. A. T. WILLMOUTH, formerly East Midlands Area Manager.

DR. R. H. HICKLEY has been appointed Metallurgist in charge of Research and Development by John M. Moorwood, Ltd., roll manufacturers, Sheffield.

MR. J. ROYCE, a well-known figure in the development of electric furnaces, has now joined Hedin, Ltd. Mr. Royce is to extend their manufacturing range to include furnaces of all types, with particular reference to sintering and the various types of atmosphere furnaces.

HONEYWELL-BROWN, LTD., announce the appointment of MR. E. B. FOSKETT as Manager of their Glasgow Office. The former Manager, MR. D. J. VENNING, has taken up a senior appointment at the Company's Head Office at Perivale.

MR. J. SHIRREFF has been appointed Vice-President of Johnson, Matthey and Mallory, Ltd., the Canadian associate of Johnson, Matthey & Co., Ltd.

MAJOR-GENERAL R. E. URQUHART, C.B., D.S.O., who commanded the 1st Airborne Division at the battle of Arnhem, has joined the staff of Davy-United in an administrative capacity.

VICKERS, LTD. announce that LT.-GENERAL SIR RONALD M. WEEKS, K.C.B., C.B.E., D.S.O., M.C., T.D., has decided to vacate his office of Chairman of the Company on May 31st next, by which date he will have passed the normal age for retirement from executive office under the Company. VISCOUNT KNOLLYS, G.C.M.G., M.B.E., D.F.C., the present Deputy Chairman of the Company, will succeed Sir Ronald as Chairman.

MR. E. H. S. VAN SOMEREN, Physicist in the Research Department of Murex Welding Processes, Ltd., recently visited Baghdad to advise the Director General of Industry in Iraq, in regard to the establishment and equipment of a spectrochemical section in the laboratory of their Department of Scientific and Industrial Research.

MR. A. R. KEY has been appointed Vice-President of Johnson, Matthey & Co., Inc., the American associate of Johnson, Matthey & Co., Ltd.

MR. G. M. PALMER is joining Vauxhall Motors, Ltd., as Assistant Chief Engineer. Mr. Palmer, who will concentrate primarily on passenger car development, becomes one of a small group of senior engineering executives reporting to Mr. M. Platt, the Chief Engineer.

SUNVIC CONTROLS, LTD., announce the appointment of MR. O. L. WELBORN as General Representative for the South-West Area, and of MR. W. J. DONNELLY as Technical Representative for the Midlands Area for their Scientific and Industrial Division.

Obituary

We regret to record the death of :—

MR. R. L. POTTER, who died suddenly at his Welling home, as a result of coronary thrombosis, on Tuesday, October 25th. Mr. Potter, who was 56 years of age, joined the staff of Elliott Brothers (London), Ltd., in March, 1923, immediately after leaving Loughborough College. Until 1930 he worked in the Test Room, but then joined the newly-formed Heat Control Division, which he helped to found. Towards the end of the same year, he was appointed as the Division's first Service Engineer and, in the years that followed, as Service Manager built up the present Service Department. Mr. Potter was later appointed Divisional Sales Manager, a position he held at the time of his death.

Forthcoming Meetings

3rd January

Institute of Metals, Oxford Local Section. "Patents," by T. M. CONNELLY. Ballroom of the Cadena Cafe, Cornmarket Street, Oxford. 7 p.m.

4th January

Institute of Welding, Manchester and District Branch. "Twenty Years of Welding Development," by H. E. LARDGE. Reynolds Hall, College of Technology, Manchester. 7.15 p.m.

Institute of Welding, North London Branch. "The Brittle Fracture of Mild Steel—A Survey," by DR. C. F. TIPPER. Manson House, Portland Place, London, W.1. 7 p.m. for 7.30 p.m.

Institution of Engineering Inspection, Birmingham Branch. "Methods of Production and Inspection of Bonded Structures," by a Representative of AERO RESEARCH, LTD. Birmingham Exchange and Engineering Centre. 7.30 p.m.

Institution of Production Engineers, Wolverhampton Section. "Forgings and Pressings in High Strength Aluminium Alloys," by J. E. EARL. Wolverhampton & Staffs. Technical College, Wolverhampton. 7.15 p.m.

5th January

Institute of Metals, Birmingham Local Section. "Recent Developments in Foundry Practice," by DR. D. V. ATTERTON. James Watt Memorial Institute, Great Charles Street, Birmingham. 6.30 p.m.

Institute of Metals, London Local Section. "Grain Boundaries," by DR. D. MCLEAN. 4, Grosvenor Gardens, London, S.W.1. 6.30 p.m.

Leeds Metallurgical Society. "The Production of Pure Metals," by DR. J. C. CHASTON. Large Chemistry Lecture Theatre, The University, Leeds, 2. 7.15 p.m.

6th January

Society of Instrument Technology, Fawley Section. "Metals and their Uses—also The Use of X-Ray with Metals," by V. COTTON. Copthorne House, Fawley, Hants. 7 p.m.

10th January

Incorporated Plant Engineers, Edinburgh Branch. "Materials Handling," by J. FINDLAY. 25, Charlotte Square, Edinburgh. 7 p.m.

Institute of Metals, South Wales Local Section. "Hard Metals," by H. WILLIAMS. Department of Metallurgy, University College, Singleton Park, Swansea. 6.45 p.m.

Institution of Engineering Inspection, Coventry Branch. "Glass Blowing for Research Apparatus," with demonstration by W. V. BAKER of the Research Labs. of B.T.H. Co., Ltd. Coventry Technical College (Room A.5). 7.30 p.m.

Institution of Engineering Inspection, Leeds Branch. "Photoelasticity," by DR. J. WARD. Theological Library, Leeds Church Institute, Albion Place, Leeds, 1. 7.30 p.m.

Institution of Engineering Inspection, South-Western Branch. Film: "Hard Metal," by PROLITE, LTD, represented by R. J. Porter. Grand Hotel, Broad Street, Bristol. 7.30 p.m.

11th January

Incorporated Plant Engineers, Leicester Branch. "Rust Prevention," by JENOLITE, LTD. Leicester College of Art and Technology, The Newarkes, Leicester. 6.30 p.m.

Institute of Welding, Medway Section. "Through the Welding Arc," by W. K. B. MARSHALL. The Sun Hotel, Chatham. 7.30 p.m. for 7.45 p.m.

12th January

Incorporated Plant Engineers, Merseyside and North Wales Branch. "Radiography in Industry," by E. J. GRIMWADE. Royal Institution, Colquitt Street, Liverpool. 7.15 p.m.

Institute of Welding, South London Branch. "Tubular Steel Design," by R. G. TAYLOR. 2, Savoy Hill, London, W.C.2. 6 p.m. for 6.30 p.m.

Liverpool Metallurgical Society. Discussion on Modern Techniques of Metallurgical Analysis. Liverpool Engineering Society, 9, The Temple, Dale Street, Liverpool. 7 p.m.

13th January

North East Coast Institution of Engineers and Shipbuilders. "Steel for Shipbuilding," by T. F. PEARSON. Mining Institute, Newcastle upon Tyne. 6.15 p.m.

16th January

Institution of Mechanical Engineers. Joint Meeting with the Institutions of Civil and of Electrical Engineers. "Advanced Courses for Engineers in Industry," by DR. W. JACKSON, H. D. MORGAN, and PROF. G. F. MUCKLOW. 1, Birdcage Walk, Westminster, London, S.W.1. 5.30 p.m.

17th January

Institute of British Foundrymen, East Anglian Section. I.B.F. Sub-Committee T.S.43 Report: "Cupola Developments," introduced by W. J. DRISCOLL. Central Hall, Public Library, Ipswich. 7.30 p.m.

Institute of British Foundrymen, Slough Section. "Foundry Dust Hazards," by E. B. JAMES and W. B. LAWRIE. Lecture Theatre, High Duty Alloys, Ltd., Slough. 7.30 p.m.

Sheffield Metallurgical Association. Annual General Meeting of the Refractories Group. "Electric Arc Furnaces—Walls and Roof," by P. F. YOUNG. B.I.S.R.A. Laboratories, Hoyle Street, Sheffield, 3. 7 p.m.

RECENT DEVELOPMENTS
MATERIALS : PROCESSES : EQUIPMENT

Pitan Bitumen Sealer

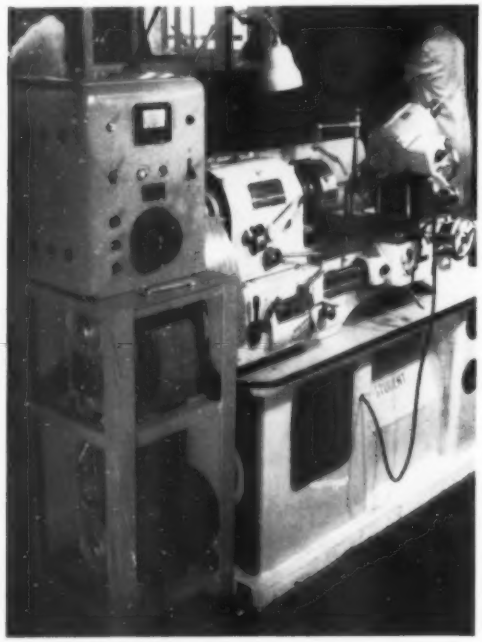
ALLWEATHER PAINTS, LTD., have recently introduced a new product—Pitan Bitumen Sealer—which has been designed for use where the maintenance engineer requires to brighten up the works but is unable, for one reason or another, to effect complete removal of bitumen present on surfaces treated with this type of material. Pitan Bitumen Sealer acts as a very successful barrier and prevents unsightly " bitumen bleed." It is supplied only in white and can be overpainted with any decorative or protective finish. A coverage of 60–70 sq. yd. is obtained from 1 gal. for which the price is 50s.

Allweather Paints, Ltd., 36, *Great Queen Street, London, W.C.*2.

Motor Speed Controller

THE PH motor controller has been developed to meet the need for a simple, reliable, inexpensive, self-contained electro speed controller for providing infinitely variable speeds on F.H.P. motors. It is housed in a grey painted metal case, suitable for wall or bench mounting, and for use with specially wound D.C. motors up to 1 h.p., which are available in a wide range of output speeds up to about 3,000 r.p.m. Operating from a 230 volt 50 cycle single phase supply, the controller provides a speed range of 30 : 1 at a substantially constant torque. As no valves are used, operation is instantaneous from cold, and smooth stepless speed control is provided throughout the range. The isolating and motor reversing switches and circuits are protected by cartridge fuses accessible from the front. Other features include an electric speed indicator ; an electric dynamic brake giving a rapid stop ; a high efficiency, as no resistances are used for speed variation ; and push button control for the motor with provision for remote operation if required.

Precision Heating, Ltd., 142*a Canbury Park Road, Kingston-on-Thames, Surrey.*

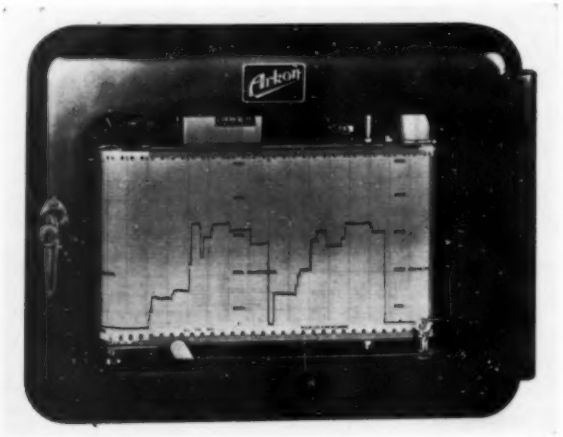


PH motor speed controller used in conjunction with machine tool.

Arkon Recorder

A RECORDING instrument to give the fullest efficient daily service should be simply constructed and easy to read. Messrs. Walker, Crosweller & Co., Ltd., have now released an interesting instrument for the measurement of gas or air flow which has been carefully designed to obviate errors due to carelessness, and to prevent misreading on the part of the operator.

Arkon Recorder Model 1601 is rectangular in shape and made of heavy gauge sheet steel with a chart 6 in. in height and ruled in straight lines. It is available either for wall or panel mounting. The visible length of the chart covers 16 hours and can be cut off daily if desired at any point of its travel, the free end being automatically gripped and wound on to a roller which can hold as much as a week's record. The chart, which travels at $\frac{3}{4}$ in./hr. and lasts six weeks, provides an extremely clear and permanent record.



Arkon recorder

The instrument is worked in conjunction with a differential pressure device, usually an orifice plate installed in the gas stream. Impulse pipes from either side of this device transmit the variations in flow to a liquid sealed bell, which is connected to a shaft rotating on ball bearings and moving a pair of cams, which, in turn, transmit the impulses to the pen arm shaft. Equilibrium is restored by a change in the tension of a spring connected to the shaft. The complete mechanism has a low inertia and friction, being sensitive to small changes

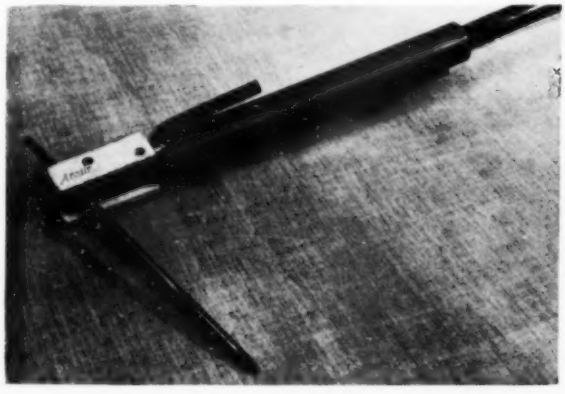
in the flow rate. The bell and spring are of stainless material.

Where these recorders are used for process control the chart record is usually sufficient, but where they are required to show total quantity of flow over a period an electrically operated integrator may be optionally fitted. The index is visible through the recorder window above the chart mechanism as seen in the illustration. Operating on a thirty-second cycle, the integrator adds up a series of spot readings and is therefore accurate despite fluctuations in rate of flow. These new recorders have a particularly interesting application for the metal industry, where they can be used for recording the consumption of gas or gas/air ratio on various types of heating and melting installations.

Walker, Crosweller & Co., Ltd., Cheltenham.

Cutting and Gouging Torch

A RECENT development in the metal cutting and gouging field is the Lincoln Arcair torch, which uses only the electric arc and compressed air, thus eliminating the need



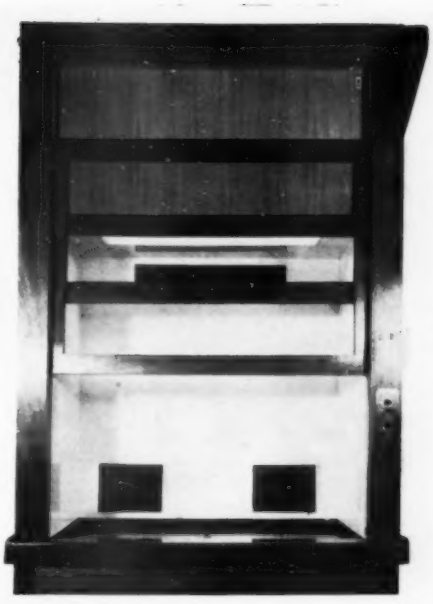
Arcair torch

for gas cylinders. The technique is claimed to work on all metals, including stainless steel, using special Arcair copper-coated graphite carbons, which are available in seven sizes—$\frac{5}{32}$, $\frac{3}{16}$, $\frac{5}{16}$, $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$ and $\frac{5}{8}$ in. The Arcair torch can readily be applied to the preparation of joints for welding, and to metal removal in the foundry. Many times faster than chipping, the process is said to be much cheaper to operate than oxygen gouging. Furthermore, the tool operates readily in restricted space and in any position, and requires no difficult adjustments for use on different materials.

Lincoln Electric Co., Ltd., Welwyn Garden City, Herts.

Fume Control Cabinet

THE Cygnamatic fume control cabinet, which is the result of the co-operation of two well-known Bolton firms, Cygnet Joinery, Ltd., laboratory furniture specialists, and Turner & Brown, Ltd., chemical plant engineers, has been designed primarily for handling radioactive compounds, but it will also be of interest to chemists handling aggressive materials. One of the main features of the Cygnamatic is the fact that it is lined with lead foil and faced with $\frac{1}{8}$-in. white Cobex rigid vinyl sheet. It is equipped with three vent grilles which carry the fumes and particles, etc., to a common scrub-



Fume control cabinet

bing unit situated at the rear of the cabinet, where the fumes are subjected to water sprays and neutralising agents before passing vertically to a mist eliminator and filter, and thence through the fan to atmosphere. The whole of the ducting, scrubber unit and fan are constructed from Cobex rigid vinyl sheet, so that contamination of the duct is reduced to a safe minimum and corrosion is non-existent. The waste water from the scrubbing duct is carried in P.V.C. or polythene waste pipes to setting tanks. The fan, one of the Turbro series, has been designed to give the following performances with the sash openings stated :

3 in.—750/800 cu. ft./min.
6 in.—280 cu. ft./min.
12 in.—100 cu. ft./min.
18 in.—80 cu. ft./min.
24 in.—50 cu. ft./min.

The sash, which is built up from rigid P.V.C. and armoured glass, is lowered and raised by a " dead man " safety switch.

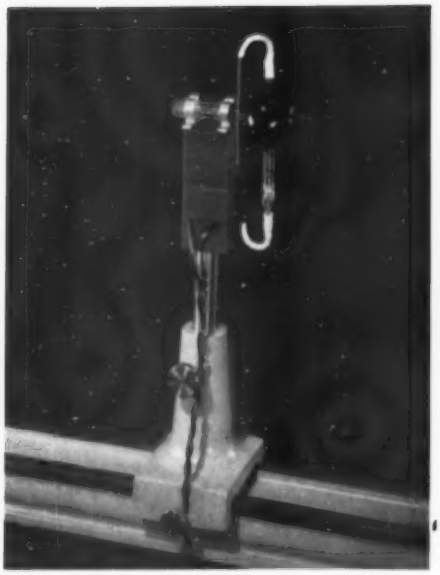
Cygnet Joinery, Ltd., Bolton.
Turner & Brown, Ltd., Bolton.

Hollow Cathode Lamps

THE development of the hollow cathode lamp has been described by Tolansky* particularly for the study of hyperfine structure. Although its extreme steadiness makes it an ideal line source for general work, it has found little application outside the high energy field, because of the complicated auxiliary equipment that has hitherto been found necessary, in the form of a vacuum system with various traps, an auxiliary discharge tube, and a diffusion pump of somewhat special pattern, to maintain a circulation of an appropriate rare gas through the lamp and the attached system.

Encouraged by the success of A. Walsh of C.S.I.R.O. Melbourne, Australia, Hilger & Watts are now able to prepare such lamps in a permanently sealed off form, so

* Tolansky "High Resolution Spectroscopy," Methuen & Co. London (1947).



Hollow cathode lamp

that they may be mounted on a Barfit stand on a Hilger standard accessory bar. The lamp is mounted on a plug which fits a socket on the Barfit stand so that one lamp may be immediately substituted for another without disturbing any other part of the apparatus. About 750 v. are required for the operation of these lamps with their ballast resistors, and a compact power unit for this purpose for operation from A.C. mains can be supplied. The simplicity, steadiness and fineness of the lines makes these lamps ideal for producing reference spectra. They are made with silica windows sealed through a graded seal so that their usefulness is extended to the ultraviolet spectrum.

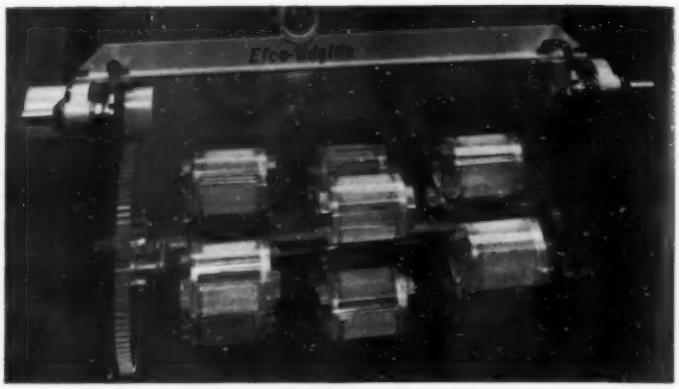
Hollow cathode lamps with iron or copper cathodes are normally available from stock, and enquiries are invited for lamps containing other elements, about 20 of which have already been produced experimentally.

Hilger & Watts Ltd., 98 St. Pancras Way, Camden Road, London, N.W.1.

Cluster Barrel Plating

In the course of manufacture of small metal component parts such as rivets, screws, etc., the plating industry and engineering works in general have often felt the need of some form of fully immersed plating barrel suitable for a variety of processes in which small batches of different types of articles can be plated at the same time. The recent development of the Efco-Udylite Perspex cluster barrel affords a solution to this problem which will be widely welcomed.

A cluster barrel consists of twelve containers fitted on to a central shaft by means of suitably insulated spring clamps. The main shaft and spring clamp carry the current to the containers by cable to two horns on the main structure. Since the structure is identical with the standard barrel equipment supplied by Efco, it will fit into the normal plating sequence, and is suitable for all types of cleaning processes and plating solutions, except those for bright zinc and chrome.



Efco-Udylite cluster barrel

The cluster barrels are made in Perspex with stainless steel cathode contact plates and bayonet type lugs. All lids are interchangeable with each other and the barrel assemblies themselves are interchangeable, so that additional containers can be used to avoid delay during loading and unloading. The Perspex construction is unique, in that the barrels can be taken through hot alkali cleaner, water rinse, acid dip, and acid or alkali plating processes, without any intermediate transfer of work being necessary, with a consequent material decrease in handling costs.

The external dimensions of the containers are 5 in. in diameter and $7\frac{3}{8}$ in. long and each will hold approximately $4\frac{1}{2}$ lb. of 2 B.A. nuts. The current drawn on various solutions varies according to conditions; as an example, in a recent test with 50 lb. in 10 barrels the current drawn was 380–410 amps at 15 volts for bright nickel. An idler pinion between the existing drive pinion and the Perspex ring gear enables the barrel at all times to be fully immersed in the plating solution.

Electro Chemical Engineering Co., Ltd., Queens Road, Weybridge, Surrey.

Mild Steel Welding Electrodes

The Quasi-Arc Co., Ltd., recently announced the addition of Ferron electrodes to their well known range of rods for welding mild steel. The new electrodes are designed for the welding of mild steel in all positions, particularly heavy sections or joints of a highly restrained nature; also for welding commercial steels of higher carbon, alloy or sulphur contents than normal mild steel of welding quality. They are suitable for engineering and shipbuilding applications where weld metal having a low transition temperature is essential; moreover, the sound fine-grained weld metal deposited makes them especially suitable for pressure vessel work where a high standard of radiographic examination must be met.

Ferron electrodes are made in sizes 12 s.w.g. to $\frac{5}{16}$ in. diameter. They comply with B.S.639 : 1952 and are approved by Ministry of Transport and Civil Aviation, and Lloyd's Register of Shipping for welding mild steel in all positions. Other approvals are pending. Full details are given in Technical Circular T.C.922 available on request.

The Quasi-Arc Co. Ltd., Bilston, Staffs.

CURRENT LITERATURE

Book Notices

WELDING TECHNIQUES AND USES IN THE UNITED STATES

Report of O.E.E.C. Technical Assistance Mission No. 143, 116 pp., numerous illustrations. Obtainable from H.M. Stationery Office and other organisations handling O.E.E.C. publications. 7s.

MANY new applications are nowadays being found for welding, especially in the machinery and building industries. Moreover, new equipment exists which makes possible the mass production of welded parts, or the application of welding processes to metals formerly considered unsuitable for welding. Along with these developments comes a growing need for specialised training amongst engineers and craftsmen. The Americans have made great progress in this field in recent years. The tasks of O.E.E.C. Mission No. 143 were to study their organisation of research and technical training, and to learn their latest methods, equipment and applications. The Mission's report makes this knowledge available to all "European welders."

The section of the report dealing with technical developments is well illustrated and gives a clear idea of some pieces of equipment designed to increase productivity in processes common to many industries. It includes chapters on testing and inspection, new welding processes, handling devices, and structural welding. The Mission's findings were considered so interesting and useful that a second Mission is at present working on a comparative study of the same subject in Europe. Its report will be published towards the end of the year.

THE PAINTING OF STRUCTURAL STEELWORK

Third Interim Report of Joint Technical Panel J/P1 of the British Iron and Steel Research Association. 40 pp., numerous illustrations, charts and tables. 1955, B.I.S.R.A., 11, Park Lane, London, W.1. 5s.

IN the past, constructional engineers regarded the final painting of structural steelwork as a relatively minor consideration. The usual practice was to cover the new erection with a red lead primer and a top coat of any paint available. But rising costs have made such a policy progressively uneconomic, and a more scientific approach has therefore become essential.

Assessing protective schemes is not a simple matter, and if done with the necessary thoroughness takes a very long time. With these facts in mind B.I.S.R.A. and the British paint industry started four long-term investigations between 1945 and 1948; these involved priming paints made from a variety of pigments and media, protective paints based on tars and bitumens, metallic coatings, and methods of surface preparation. These last two aspects of the problem have assumed a particular importance over recent years.

Many hundreds of test specimens were prepared and exposed at the two selected sites. One, at Brixham in Devon, provided a mild seaside atmosphere, while the other, at Derby, was in a severely corrosive industrial atmosphere. The contrast between the two is shown by the fact that bare steel corrodes about three times as quickly at Derby as at Brixham; on the other hand the rate of paint breakdown at Brixham is increased by the longer periods of sunshine there. Mild steel plates, 15 × 10 in., were used throughout, the thickness being $\frac{1}{4}$ or $\frac{3}{16}$ in.

These investigations, started so many years ago, have begun to yield interesting results. It has been shown, for example, that twenty of the priming paints under test gave better protection than the conventional red lead in linseed oil paint. Several of these paints contained chromate pigments bound with a linseed oil medium; other examples based on alkyd vehicles were pigmented with a mixture of non-leafing aluminium powder and basic lead sulphate, or, alternatively, zinc oxide. These latter paints are much easier to apply than the old-fashioned red lead formula, and it will be interesting to see whether the promise shown in the tests is confirmed in actual working experience.

The superiority of grit-blasting as a preparatory method was clearly established, and the value of phosphating also demonstrated. The tests have not proceeded long enough to furnish a reliable comparison of the merits of zinc and aluminium coatings as a basis for paint, but there are already indications that coatings of these metals, 3 mils thick, are superior to the conventional terne plate, 1 mil thick.

The results of these researches are now published in the Third Interim Report of Joint Panel JP/1 of B.I.S.R.A., entitled "Painting of Structural Steelwork." Almost every page of this Report carries information of the utmost use to the practical engineer who wishes to reduce maintenance costs and prolong the life of steel structures, presenting a forty-page record of scientific work designed to this end.

Trade Publications

ONE of the earliest recorded electric uses of aluminium was in the form of bus-bars which were installed at Niagara Falls in 1895. Since that time the use of aluminium in the electrical industry has grown considerably and Aluminium Union, Ltd., have recently issued leaflets dealing with its uses in bus-bars and in overhead systems for railway electrification.

WE have received from Fry's Diecastings, Ltd., a new technical publication dealing with the finishing of aluminium bronze diecastings. The operations dealt with include the preliminary cleaning processes (degreasing, bright dipping and polishing); painting and enamelling; solution bronzing; and electroplating. Copies may be obtained from the Company's Midland Works, Brierley Hill Road, Wordsley, near Stourbridge. ENTITLED "A New Way of Looking at Fuel Economy," a leaflet issued by Morgan Refractories, Ltd., discusses the way in which M.I. hot-face insulating refractories can help to reduce fuel consumption by straightforward insulation and by the effect of their low thermal capacity. FROM the basic forms of Araldite Type 1 rods and powder, a surface coating and a casting resin, available in 1948, a whole range of epoxies for bonding, sealing, impregnating, potting, filling and coating has now been developed.

Some details of the various forms now available and of their uses are published in Aero Research Technical Notes (Bulletin No. 151) issued by the Technical Service Department of Aero Research, Ltd., Duxford, Cambridge, who are associated with Ciba, Ltd., of Basle, who developed these resins.

At a time when the problem of atmospheric pollution is receiving increasing attention, W.C. Holmes & Co., Ltd., of Huddersfield, have issued a booklet introducing the Holmes-Schneible Multi-Wash System, which is now available in this country. This system is applicable to many problems involving the collection and cleaning of dust laden air and other gases, and copies of the booklet (Publication No. 54) can be obtained from the Company's Advertising Department.

Several new leaflets have been issued recently by Edwards High Vacuum, Ltd., to supplement their catalogue on vacuum equipment. Leaflet D.153/1 deals with the "Philani" vacuum gauge, a combination of the well-tried Philips and Pirani type gauges. The Model 3 ionisation gauge control unit is described in Leaflet D.141/4, whilst the Edwards gauge summary has been re-issued as Leaflet D.111/2. Leaflets dealing with vacuum accessories include C.107/4 ("O" ring vacuum seals); C.124/1 (vacuum unions and flanges); C.111/4 (fine control needle valves); and C.100/5 (magnetic vacuum valves). Finally, Leaflets E.108/4 and E.101/5 describe the small 6E and 12E vacuum coating units, and E.144/2 gives details of the evaporation filaments, baskets and boats available, while H.106/2 provides information on suitable evaporation materials and recommended suppliers.

The first close-to-form compressor blade for the axial flow gas turbine engine was made in 1940 by High Duty Alloys, Ltd. Since that time 20 million such blades have been made. This represents but one aspect of the activities of High Duty Alloys Forging Division at Redditch. In a recent publication entitled "Aircraft Stampings," pictorial evidence is given of some of the other types of forgings supplied to the aircraft industry.

We have received from May and Baker, Ltd., a new price list for photographic chemicals, which include a wide range of developers.

We have received from Wild-Barfield Electric Furnaces, Ltd., an 8-page leaflet on carbonitriding, which discusses the mechanism of the process and the way it is applied, using a prepared town's gas atmosphere, or an atmosphere obtained by pyrolising Carbodrip liquid. Reference is made to batch, rotary drum, and shaker hearth furnace procedures.

In the October issue of *The Bonderizer*, published by The Pyrene Co., Ltd., there is an article on the Bonderizing of zinc alloy die castings used in the manufacture of Dinky Toys at the Speke Works of Meccano, Ltd. There are also articles on protecting tube fittings (which describes an ingeniously designed plant employed by Stewarts and Lloyds, Ltd., for continuously Parkerizing and varnishing a wide variety of units) and on Frenger's thermal acoustic ceiling (in which aluminium alloy panels are protected against corrosion by Pyluminizing).

Tin-nickel plating, developed by the Tin Research Institute, has been used for the protection of balance weights, and this application is discussed in the October issue of Baird and Tatlock (London), Ltd.'s *Bulletin and Laboratory Notes*. Other items of interest include bomb-firing units, low temperature thermostat baths, and laboratory stirrers.

Publication 377, issued by George Kent, Ltd., is concerned with the Kent Gas-Pressure Controller, which is a blind-setting instrument suitable for maintaining pressure with great accuracy at any value between − 6 in. and + 6 in. w.g.

Since its foundation as a gear making firm in Huddersfield in 1860, The David Brown organisation has grown considerably, particularly in the last 20 years, until today, in addition to 15 manufacturing units in various parts of the United Kingdom, and associated companies in Eire, Canada, Australia and South Africa, it is served by an extensive network of distributors, agents, branch offices and representatives in many countries. Today it is concerned with the production of gears, gear cutting plant, agricultural and industrial tractors, machine tools, precision tools, steel and bronze castings and luxury automobiles. A new illustrated brochure is designed to show how the resources and enterprise of David Brown have contributed to the development of practically every industry in all parts of the world.

A new publication, "The Present ... The Future," issued by the General Electric Co., Ltd., covers many aspects of the present state and future outlook for the electrical and electronic industries. It illustrates its theme by a series of short surveys of topics of urgent importance in which the Company has a specialist interest. These include the influence of atomic power on the future generation of electricity, the growth of automation in industry, developments such as inter-city dialling in tele-communications, and new materials and techniques with a future. Later chapters deal with the Company's contribution to Britain's defence, railway modernisation, future research and education for leadership in industry.

Books Received

"Brazing Manual." Prepared by Committee on Brazing and Soldering—American Welding Society. 193 pp. inc. index. New York and London, 1955. Reinhold Publishing Corporation and Chapman and Hall, Ltd. 38s. net.

"Vapor-Plating—The Formation of Metallic and Refractory Coatings by Vapor Deposition." By C. F. Powell, I. E. Campbell and B. W. Gonser. 158 pp. inc. author and subject indexes. New York and London, 1955. John Wiley & Sons, Inc., and Chapman & Hall, Ltd. 44s. net.

"Rapid Detection of Cations." By G. Charlot, D. Bézier and R. Gauguin. Authorised translation by R. E. Oesper. 92 pp. London, 1955. Thames & Hudson, Ltd. 9s. 6d. net.

"Electric Dipole Moments." By J. W. Smith. 370 pp. inc. author and subject indexes. London, 1955. Butterworths Scientific Publications. 42s. By post, 1s. 9d. extra.

"Proceedings of the Sixth Meeting of the International Committee for Electrochemical Thermodynamics and Kinetics." The papers and discussions have been prepared for publication under the direction of the Editorial Board of C.I.T.C.E. 567 pp. London, 1955. Butterworths Scientific Publications. 84s. By post, 2s. extra.

LABORATORY METHODS
MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS

DECEMBER, 1955 Vol. LII, No. 314

Some Aspects of Hardness Testing

Report of International Conference in Bremen

At the recent Hardness Testing Conference in Bremen the papers presented covered the four main standard methods of testing—Brinell, Vickers, Rockwell and Shore—as well as microhardness testing, the aspects discussed ranging from the shape of the indenter to the use of special techniques for measuring the hardness of internal surfaces, and from the accuracy and reproducibility of results to correlation of the various hardness scales. A brief report of the proceedings is presented here.

THE International Conference on "Hardness Measurement in the Workshop," held in Bremen in September, was attended by the same success as the first International Conference in Bremen in 1952 and the 1953 Hardness Testing Conference in Sheffield. At the conclusion of this year's meeting a discussion between the organisers and a group of foreign representatives resulted in agreement to collaborate internationally in the field of hardness testing, with a view to reaching a better understanding and, ultimately, international standardisation of hardness testing procedures.

Microhardness Testing

The Conference opened with the presentation and discussion of two papers by DR. BÜCKLE, of Paris. The first dealt with "The Relation between the Aim and the Measuring Methods of Microhardness Testing," and the second with "True and Apparent Sources of Error in Microhardness Testing." Microhardness testing was first used about twenty years ago, and the first difficulty encountered by the pioneers was that the microhardness value is generally higher than the macrohardness figure. This is due to the fact that microhardness is load-dependent, whereas macrohardness is usually independent of the applied load. New hardness definitions have been introduced and the establishment of a relationship between micro- and macrohardness attempted.

A further disappointment arose from the fact that in microhardness testing variations from 30 to 50 and even up to 100% occurred. A good example of this is to be found in published microhardness data on aluminium. In order to progress in this field, a systematic investigation of the basic principles of microhardness testing is urgently needed, and in this connection the author attempted to distinguish between the avoidable and the unavoidable sources of error, so that the elimination as far as possible of the known causes would leave only those which are not actual sources of error, but characteristics of microhardness itself. The effects of true sources of error (reading errors, deformation through polishing, etching films, vibration, loading speed, indenter errors, etc.) are particularly pronounced in the case of the smallest indentations, up to a diagonal length of 50 micron, as are those due to the structure of the metal (heterogeneity, diffusion, inclusions, texture, etc.). For indentations above 30 micron, these effects gradually disappear, leading ultimately to a straightforward law of simple load-dependence. Whilst true microhardness testing (load 1–50 g.) is a scientific investigation method which should only be carried out by specially trained personnel, less stringent conditions apply in the case of low-load hardness testing (load 100–200 g.). In this procedure, arbitrary variations are avoided by the use of correctly constructed machines by personnel conversant with fine measurement, and by the application in each instance of the largest possible load.

Dr. Bückle further warned against arbitrary transition from the low-load field to the microhardness and macrohardness fields In particular, he recommended the use of calibration curves of a given material which has been tested in both the micro- and macrohardness ranges. In this way the variations arising could be considerably reduced.

R. SCHULZE, in the discussion of Bückle's paper, emphasised the importance of the elastic recovery of hardness indentations. Recent work has shown that the shortening of the diagonal of the hardness indentations can be measured by special techniques, for instance by means of soot coatings. In such investigations no true shortening was observed, so that the factor c introduced by Schulze cannot be considered as a measure of elastic recovery, but only as a correction factor for the diagonal length. On the other hand, appreciable elastic recovery in depth has been shown by interference photographs. The calculated values can be brought into relationship with the modulus of elasticity.

A. KRISCH and G. SCHIMMEL referred to the necessity of using an electron microscope for small test loads, a problem which was discussed in the next paper by KAZUHIKO AKASHI, who used a diffraction grating with 1,152 lines per millimetre (29,500 lines per inch). He superimposed the indentation image over the diffraction grating by a double exposure on the same film. The division of the grating was uniform within $\pm 0{\cdot}1$ micron. Tests on a carbon steel, which had been

electrolytically polished after hand lapping, indicated no load-dependence of microhardness. Further tests are to be made before any definite conclusion is reached on this point, however.

The Vickers Method

E. B. Bergsman and J. Travaillé reported on their researches on the Vickers method of hardness testing, and on the relationship between Vickers hardness and Brinell hardness values. The diamond pyramid number is usually considered an ideal hardness number, but it should be remembered that neither the material to be tested nor the diamond pyramid itself is ideal. Even in the case of an ideal—i.e., isotropic—metal which has not been cold worked, a pyramid-shaped indenter never produces a perfectly square indentation. This arises from the fact that the material is non-uniformly displaced along the pyramid faces, so that after removal of the load a barrel-shaped indentation with curved faces is left. According to recent work, in the calculation of hardness values one should consider not the surface of an ideal square indentation, but the total deformed surface. Errors of this type may be avoided by the use of a ball or cone indenter. The different types of diamond pyramid indentations on a range of materials were carefully investigated and an attempt was made to relate them to the properties of the material.

In the discussion Professor Pfender explained the behaviour of the diamond pyramid in terms of the change in path of the compressed material along the pyramid surface. The path is shortest in the middle of the pyramidal face, and a maximum flow of material is to be observed at this point. P. Grodzinski pointed out that the ratio of indentation surface to surface of the indentation, which Bergsman required to be a constant value, is also a constant value for the double-cone diamond, as was shown recently. Grodzinski agreed that the production of an accurate diamond cone is very difficult, but stressed the possibility of producing multiple-sided diamond pyramids—i.e., with 16 or 32 faces—which are a good approximation to a cone.

Work Hardening During Testing

Dr. A. Krisch referred to his extensive investigation into the increase of hardness under a hardness testing indentation. Impressions were made on $14 \times 19 \times 8$ cm. steel specimens by means of a 50 mm. diameter ball and a sintered carbide pyramid ground to the Vickers form : the applied load was 75,000 kg. The specimens were sawn through the middle of the impression and the increase in hardness on the cross-sectioned face was determined by means of a low-load hardness tester. An increase in hardness to about double the initial value was found directly below the centre of the impression. Around the indentation the hardness slowly decreased.

Lines of equal hardness have an elliptical shape in the case of both ball and pyramid indentations. Below the Brinell indentation a uniform distribution of hardness was found, whereas the centre of the pyramid indentation showed a strong increase in hardness, which suggests a non-uniform distribution of the load.

The Rockwell Method

The latest developments in Rockwell hardness testing in the United States were discussed by V. E. Lysaght. It is generally agreed that the Rockwell method has many advantages in production hardness testing. The method was first introduced in 1921, and since that time there has been a continued increase in its application in both the workshop and the laboratory. In certain applications, the Brinell and rebound methods (e.g., using the Shore scleroscope) have been more or less discontinued. The Rockwell tester has been improved considerably, and at present a number of semi-automatic and motorised machines are available which speed up considerably hardness testing in the workshop. In one of the newest machines the supplementary load is applied by means of an oil brake, but the load can be removed again by means of a motor and cam drive. A dial gauge with automatic pointer adjustment has been developed so that there is no need for the operator to make the zero adjustment. The rapid growth of automation in the production field has led to the development of an automatic Rockwell hardness tester which is believed to be capable of 1,000–1,200 tests per hour. The components are automatically fed into the machine and brought below the indenter. After application and removal of the test loads the Rockwell hardness is indicated by the dial gauge. Accurate photo-electric transistors take the hardness indication : the value is changed into impulses operating relays and the tested material is arranged in order of its hardness.

The author emphasised that since 1920 the Rockwell hardness numbers have been guaranteed by the Wilson Instrument Company : the hardness specifications of the American automobile industry in 1955 use the same values as were known 20 or 30 years ago. Heat treated carbon steel, quenched and tempered in the same way, gives the same Rockwell value within a range of variation of $\pm 0{\cdot}5$ RC units for a hardness in the region of RC 60. For higher rates of testing, difficulties with breaking out of diamond indenters may occur, but even with rapid testing tolerances of $\pm 0{\cdot}5$ in the RC 60 region and ± 1 at RC 20 are attainable with machines in good condition.

In order to test internal surfaces and the flanks of gear teeth, special measures have to be adopted. The internal surface of large rings can be tested by allowing the rest of the ring to pass over the head of a commercial Rockwell machine, but for testing the internal surfaces of small cylindrical parts a goose-neck adaptor has had to be designed in such a way that, although its weight does not increase either the preload or the major load, it is sufficiently strong ; a guiding device holds it accurately in position. The goose-neck adaptor is fitted to the pressure arm by means of a profile piece with a conical end, as it is too heavy to be inserted into the pressure arm in the usual way.

By means of an extension for the adaptor, measurements can be made up to a depth of 5 cm. in a cylinder of about 10 cm. diameter. Deep bowl-shaped pieces, and plain collars near internal vertical faces of a part, can be tested by means of another extension piece, which makes possible measurements at distances up to 10 cm. from the edge without affecting the test loads. Cylinders up to a depth of 10–12·5 cm. can be tested by means of a special machine, which is not, however, so accurate and sensitive as the standard machine owing to its small size and the increased friction in parts of the test head. It is suitable for the machine shop testing of cylinders up to 9 cm. internal diameter. For testing the hardness of the flanks of gear teeth, the Rockwell Superficial Hardness Tester is generally used. This uses small test loads and produces a small indentation. The

gears can be held in a special fixture which also has a device for preventing possible damage to the indenter. For testing the hardness of the flanks of internal threads a goose-neck adaptor may be used, as also may an indenter of this form.

Microhardness testing was originally only intended for laboratory use and for research purposes, but it is now being used increasingly for the production control of thin materials about which the author reported at the 1953 Conference in Sheffield. Quite recently microhardness testing has also been called for in specifications covering chromium plating. The Knoop indenter is usually used, owing to its low indentation depth, which is only about half that of the diamond pyramid at the same load. Comparison tests between two Tukon hardness testers in the laboratory of the Wilson Mechanical Instruments Division and an independent works laboratory showed extremely good agreement between the results obtained on specially prepared samples by experienced testers. Further comparison tests were carried out on test plates having a thick chromium deposit, when the results again showed only differences of the order of 1 micron.

P. MELCHIOR, in discussing the Rockwell method suggested that it cannot be considered as ideal, because deviations of up to 4 Rockwell units can occur in practice. On the other hand, PROFESSOR ROSSOW referred to the experiences of workers at Renault who have tested sintered carbides of RC 70–80 with an average root mean square deviation of 0·27 RC units, and have thus shown the method to be suitable for control purposes. Similar findings have been made by the Schneider-Creusot organisation. POTYKA mentioned difficulties in using the superficial Rockwell method, due to the centring of the diamond point. For each diamond it is necessary to construct a curve, and absolute measurements are almost impossible. Reference was also made to German-developed automatic Rockwell hardness testers.

Hardness Testing in Britain

H. G. HARPER, London, gave an account of the present position regarding hardness testing in the United Kingdom, referring particularly to the work of the British Standards Institution in this field. Standard specifications have been introduced for the Brinell, Vickers and Rockwell hardness tests which are generally in conformity with other national standards. B.S. 870 attempts to set out a relationship between Brinell, Vickers and Rockwell hardness values, but draws attention to the fact that no generally valid theoretical relationship exists between the three methods, and that formulæ derived empirically from experimental results are only approximately correct for materials of the same composition, and for a given condition. Deviations from the tabulated values may be due to composition, heat treatment, cold working, or other conditions differing considerably from those used for fixing the values originally. If different loading conditions are chosen for the Brinell test appreciable deviations may arise. The table can, however, be used as a basis for rough evaluation, using the diamond pyramid scale as a reference basis.

The increased interest of engineers and metallurgists in hardness testing has led to two distinct requirements:—

(*a*) The reduction of the minimum load for testing thinner materials, and further investigation of the surface condition of thin layers, decarburisation, and the constituents of heterogeneous structures.

(*b*) The development of portable machines for hardness testing *in situ* of large components, such as rollers, gears, etc., which cannot be dealt with by the normal stationary hardness tester.

The standard Vickers diamond hardness tester is now suitable for loads as low as 1 kg., so that materials of 0·08 mm. thickness and over can be tested in line with the standard specifications.

Hardness testing has found widespread application in the United Kingdom, and has become an important and recognised technique in the non-destructive control of materials and components. Drawings including data on hardness and hardness values are interchanged between different organisations. The special conference on hardness testing held in October, 1953, in Sheffield, aroused great interest, and a special committee to cover the subject has been established by the Sheet and Strip Metal Users' Technical Association.

Accuracy and Reproducibility of Results

PROFESSOR E. ROSSOW submitted suggestions for a more accurate determination of Vickers hardness. If in specifications tolerances of ± 5 to $\pm 8\%$ are allowed, and if the reading tolerance of the diagonal length is $\pm 2\%$, with additional tolerances for the load of 0·5 to 1%, nothing remains for production tolerances after deducting the measuring inaccuracy. On evaluating the international comparison tests reported at Bremen in 1952 by the application of statistical methods to the results, an inaccuracy of $\pm 1\%$ and less can be obtained. In order to reduce the amount of calculation necessary, it is suggested that instead of average and root mean square values, the so-called median values should be used, the number of medians being reduced by forming groups. Although the omission of varying values prevents an accurate evaluation of errors, a satisfactory evaluation of the inaccuracies for all practical purposes is obtained. Examples show that even with a surface which is not good enough for diamond pyramid testing at low loads, hardness values of reproducible accuracy can be achieved. The diamond pyramid method is at a disadvantage compared with the more rapid Rockwell method, but has the advantage that a reproducible accuracy can be attained with commercial machines. The method is recommended for specifications, and for the control of test pieces: it can also be useful for continuous production control in certain instances.

In the discussion P. MELCHIOR referred to the differences in the definitions of repeatable variation and comparable variation. According to the experience of his laboratory, Vickers hardness values can be determined with a maximum variation of $\pm 1\%$, whereas Rockwell values show a difference of ± 2 units.

E. B. BERGSMAN stated that for the same razor blade steel a British laboratory returned a value of 820 kg./sq. mm., and a German laboratory a value of 880 kg./sq. mm. These differences are probably due to different calibrations of the optical systems, and Bergsman recommends the use of diffraction gratings for calibrating the microscopes.

In place of L. TSCHIRF, DR. F. GÄRTNER described a new system for carrying out Rocknell hardness tests on internal surfaces. The C-shaped goose-neck adaptors could only be considered as an improvisation, and as a result of sideways displacement errors of the order of $\pm 1{\cdot}5$ RC units are possible. In the new instrument,

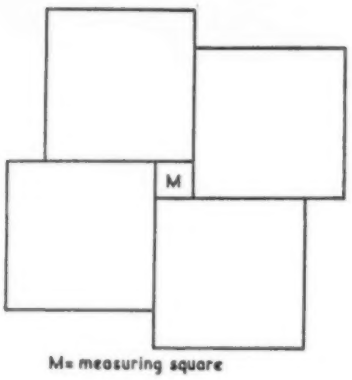


Fig. 1.—Suggested method of measuring using four blocks

the 150 kg. major load is replaced by one of 62·5 kg., and by means of a change in the length of the transmitting levers accurate Rockwell RC values are obtained. In internal measurements, the curvature has to be considered, and for this purpose formulæ and diagrams have been constructed for both concave and convex curvatures.

The Scleroscope Method

KOCHICHI OTANI discussed the reliability of the hardness values obtained with the Shore scleroscope, with which he has had some 20 years experience in testing rollers. This instrument, provided with a diamond hammer, has the advantage of being portable, and gives a direct indication of the measurement, so that it is useful for repeat checks in the workshop. A hardness number of 100 should be obtained on the Shore instrument with a specimen of quenched 1·2% carbon steel. The natural hard surface of quenched steel of this carbon content is so sensitive that no constant rebound height is obtained, and Otani believes that for the test plate a more homogeneous material is required, such as cast steel, as this is not influenced by ageing and shows no change in internal stress. Cast high carbon steel consists of cementite and pearlite, and if the Shore hardness values are determined for both components (this is discussed in detail in the paper) a relationship is obtained between the Shore hardness of the cast steel and its total carbon content: $HS = 13 \cdot 94\,C + 17 \cdot 88$. The author recommends the calibration of the instrument with the standard cast steel test plate before use.

On the question of indentation and scleroscope hardness, the author mentioned that the indentation hardness of samples of cast and quenched steels may be different when the scleroscope hardness values are the same.

Correlation of Different Hardness Scales

In discussing the confusion which exists in the correlation of values obtained by different methods of hardness testing, DR. TAKEO YOSHIZAWA referred to the various comparison tables and diagrams correlating Brinell, Vickers, Rockwell and Shore hardnesses which are used extensively in workshops and laboratories. In particular he referred to the large variations in conversion factors between Rockwell and Shore values. This may arise from the fact that roughly the same materials are used in Germany and Japan for the test plates for Rockwell hardness, whilst the Shore hardness values are higher for the same materials in Japan than in other countries. Dr. Yoshizawa also mentioned that the hardness conversion tables in the U.S.A. were changed after 1940, following the publication of the results of investigations by T. H. Gray and H. Scott. He also mentioned that the Shore hardness numbers of the Shore Instrument Company seemed to be lower for the same materials than the corresponding hardness numbers of the Japanese Standards Committee.

International Standardisation

K. MEYER, of Bremen, discussed the comparability of hardness values, a matter of considerable international importance in the material testing field. As hardness testing is applied metrology, there was developed in the period 1941–43 a standard testing machine which featured a direct load and direct measurement of depth. By thus avoiding the usual instrument errors it is possible to measure hardness much more accurately than with the usual hardness testers. At the same time, hardness test plates were produced with hardness variations reduced to 0·4 RC units. The indenting diamond influences the results obtained, and an extensive investigation showed that the diamond itself could introduce an error of ±1·5 RC units for hardness values of RC 50 and over, and of ±1·2 RC units for hardnesses below RC 50. These variations can be reduced to ±0·8 RC and ±0·7 RC, respectively, by the use of a correction suggested by the author.

An attempt at international standardisation in Rockwell hardness testing has been made during the last three years. The same hardness test plates were sent to different official and semi-official test laboratories in Austria, France, Germany, Sweden, U.S.A., U.S.S.R. and the United Kingdom, with an instruction to make 5 indentations on the plates with the available standard instruments and standard diamonds. The results of this investigation showed differences of up to 4 RC units among the values determined in the different laboratories, which cannot be considered to be satisfactory. A second series of tests was then made in which two test diamonds, in addition to the test plates, were submitted to the various laboratories. Differences were still found, amounting this time to 2 RC units. The remaining errors, apart from the shape of the diamond, may be due to the fixing of the diamond, the speed of application of the load, the duration of loading, and errors in the test apparatus. The indenter itself may have errors in its macro- and micro-geometry, and standardised tests on a large number of indenters showed that errors of not less than 0·8 RC can occur. The methods used for measuring the indenter vary from laboratory to laboratory, and the author believes that standardisation of method might be advantageous. He himself has developed several measuring methods. In one of these he measures a cone in 16 different planes in such a way that angular errors of ±30″ can be observed. Former methods of measuring the radius, too, cannot be regarded as satisfactory. In the case of the Rockwell B method, which uses a steel ball indenter, the suggestion is made that cylinders integral with half spheres should be used for accurate measurement instead of solid spheres.

In the Vickers diamond pyramid method, the sources of errors related to the diamond are absent. In this case there are only (*a*) human errors, and (*b*) optical errors in the instrument. With hardness testers equipped with projectors, reading errors up to 2 micron were found. The author used his standard Rockwell machine with

the addition of an optical measuring device instead of a standard Vickers instrument, as the latter was not available. Considerable difficulties are met with in the measurement of the square indentation, and a method was suggested of producing a square for measuring by using four gauge blocks (Fig. 1), but this was not successful. In a more recent attempt a diamond prism of accurately square cross section is measured diagonally by a mechanical contact method and then embedded in metal prior to measurement by optical methods (Fig. 2). The difference between the two readings gives the personal error of the operator including the influence of the optical conditions of the optical measuring device. The test plates developed for the Rockwell test are quite suitable for Vickers testing, provided they are lapped.

In the discussion, P. MELCHIOR inquired whether a sintering in of the test diamond in hard metal is to be recommended.

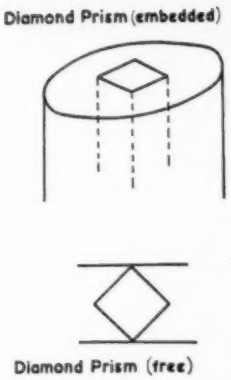


Fig. 2.—Prism embedded in metal in preparation for optical measurement.

Measuring Errors

DR. HILD, Physikalisch-Technische Reichsanstalt, reported on his investigations into the reduction of measuring errors. For this purpose, Rockwell diamond cones were made with included angles ranging from 115° to 125° and radii from 156 to 254 micron. In the 20–65 RC range, the different cone angles only affected the indicated hardness by ±1%, but the change in radius accounted for a ±10% change in indicated hardness in the same hardness range. It would therefore be advantageous to acquire an ideal diamond with the smallest possible tolerances. The author gave as probable errors in Rockwell hardness testing the following (the $\triangle H_{RC}$ figures are root mean square values) :—

H_{RC}	20	30	40	50	60	65
$\triangle H_{RC}$	±1	±0·94	±0·77	±0·67	±0·53	±0·54

PROFESSOR ROSSOW mentioned that for standard test plates chromium steel is used in Germany and plain carbon steel in Japan. Harper referred to the fact that the test plates for the Vickers machine vary in material according to the hardness range for which they are to be used. Up to 300 V.P.N. a 0·3% carbon nickel-chromium-molybdenum steel is used, whilst a 0·9% carbon steel containing 1% nickel and 0·5% chromium finds application in the range 500–800 V.P.N. Annealing is not a satisfactory treatment, and isothermal treatment has been found to give better results. After heat treatment the test plates should not be ground. They must therefore be ground to a surface finish of 2 micro-in. CLA height before heat treatment, and the grinding depth for finish grinding should not exceed 0·0005 in. for each pass. The finishing is by diamond polishing.

Hardness Testing Indenters

P. GRODZINSKI recalled that Meyer had referred to two errors in hardness testing diamonds, i.e., errors in their macro- and micro-geometry. He would like to add two further sources of errors, viz., quality and orientation. In general, the quality of a diamond can be determined only with difficulty, if at all. On the other hand, the orientation of a diamond can be accurately determined by X-ray diffraction methods. As diamond has different moduli of elasticity in different crystallographic directions, it is possible that these differences will influence the results obtained when testing at high loads. Some years ago it was suggested that a series of Rockwell diamonds should be made with the axis accurately located in specific directions, e.g. (100), (110) and (111) directions. Unfortunately this work could not be completed owing to lack of support, in spite of the fact that the orientated test diamonds were almost finished.

A further important aspect of hardness testing indenters is the standardisation of sockets. An inquiry in 1949 showed that, in the main, six different forms of socket were used, but a recent repeat inquiry established that in the meantime the figure has increased to 24 types for macrohardness testing and 6 for microhardness testing.

Uniform dimensions for hardness testing diamonds were suggested in Germany during the war, but this draft does not seem to have led to the issue of a standard. There are no basic relationships between the shape of the hardness testing diamond and the shape of the holder, and it would be a considerable advance if the manufacturers of diamond tools and the hardness testing machine makers would get together with the users of the machines and agree to a uniform socket, or at least a small number of standard sockets. This would greatly facilitate the production of hardness testing diamonds, as the standard sockets could be supplied directly from stock. Maker and user of hardness testing machines could then determine satisfactorily whether an error of a certain instrument might be due to the incorrect shape of the diamond indenter. Institutes such as that in Bremen, would probably have difficulty in adapting diamonds for machines requiring different intermediate sockets.

Hardness Test Plates

TETSUTARO MITSUHASHI reported the results of his investigations into the influence of heat treatment in the production of hardness test plates in eutectoid steel (0·84–0·87% C). The best annealing treatment was found to comprise heating at 780° C. for 90 minutes followed by slow cooling to 600° C. in five hours. For hardening the plates should be quenched from 820° C. to 350° C. in a 4% sodium hydroxide solution, followed by oil cooling. One hour at 100° C. was found to be the most suitable tempering treatment, as a temperature of 200° C. resulted in a fall in hardness. The effect of sub-zero cooling on the hardness distribution of steels containing 0·77–1·29% carbon was also investigated. Although the hardness in the fully hardened condition was increased, no clear relationship between hardness and cooling conditions was obtained. The hardness distribution was improved by the low temperature treatment, which was preferably carried out in two stages, at −30° C. and −75° C., rather than in

one stage at −75° C. Incorrect grinding and polishing can lead to tempering of the sample plate and a worsening of the hardness distribution. The hardness values obtained with the diamond pyramid machine were more reliable than the scleroscope readings.

Results of tests on a range of materials with varying heat treatment were presented by DR. TAKEO YOSHIZAWA who included the following materials : cast iron, stainless steel, eutectoid steel and chromium steel. The tests were carried out in different laboratories, and investigation of the test plates of the Shore Instrument Company showed that the heat treatment was not satisfactory. An extensive study of the storing of test plates was then made. The Tokyo Metropolitan Industrial Institute has a standard Vickers hardness tester, and carries out investigations of hardness indenters (Vickers and Rockwell) as well as of test plates (Rockwell and Shore).

Dynamic Hardness Tester

In the dynamic pendulum tester developed by K. YAMAMOTO, the impact velocity (60–200 cm./sec.) and the impact energy (5–50 g.m.) can be varied arbitrarily. The pendulum is exchangeable with the conical indenter, and it can be electromechanically lifted to different impact angles and dropped. The dropping height can be determined with an accuracy of 0·5%, and the rebound height is recorded on a photosensitive paper band, by means of a light point, at a magnification of ×10. The sample is protected after the impact by a rubber plate, to prevent a second rebound. A secondary pendulum allows the indentation process to be followed photographically. To date, no test results are available.

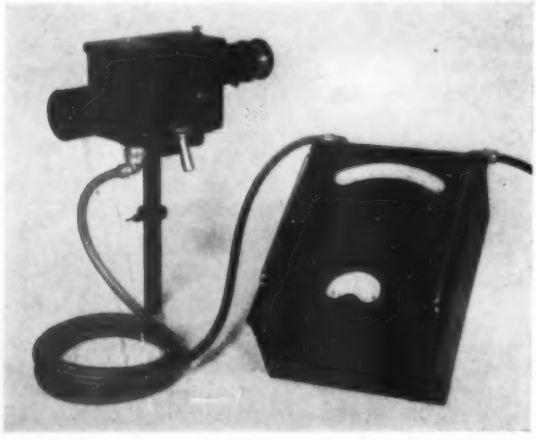
Exhibits of Metallurgical Interest at the Physical Society Exhibition

The exhibits at the Physical Society's annual exhibition of scientific instruments usually include a number of interest to workers in the metallurgical field. This year was no exception and in this issue we continue a short series of reviews in which such items will be described.

Temperature Measurement and Control

THE proportional temperature controllers shown by C.N.S. Instruments, Ltd., regulate the process power input in proportion to the integrated temperature error by intermittently switching the whole or part of the heating element. They are electronically operated and are of two types, one for use with resistance thermometers and the other with thermocouples. The accuracy of control of the latter is ± 1 microvolt.

The Foster Instrument Company's indicating temperature controller follows normal practice for temperature indicators of the deflectional type and uses the moving-coil system with pointer and scale. The only modification made is the addition of a light metallic vane to the pointer, arranged so that it lies in a plane perpendicular to the pointer and is in electrical contact, through the pointer, with one terminal of the moving coil. Two similar vanes are mounted on the control arm and arranged so that the vane or the pointer moves between them as the temperature approaches the control setting. These vanes form a capacitor, which is part of an oscillatory circuit connected to a trigger circuit, which in turn controls the action of a relay. This system of control is virtually instantaneous in action.

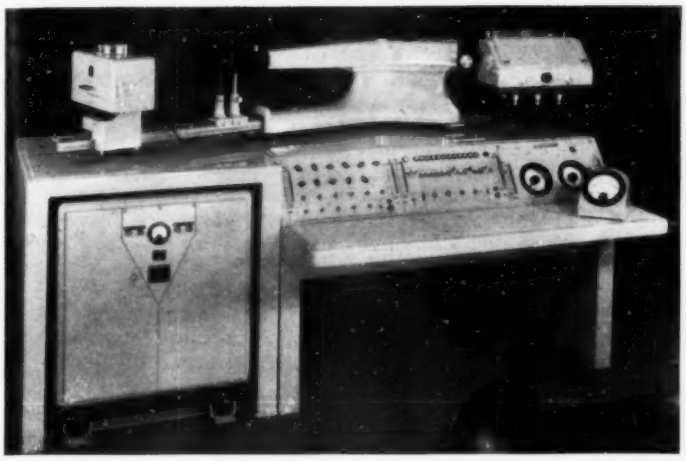


Cambridge infra-red pyrometer

The same Company's continuous balance electronic potentiometer was shown in three forms : circular-chart and strip-chart indicator recorders and a circular-scale indicator. These instruments can be fitted with various forms of control contacts for both electrically-heated and fuel-fired furnaces, and they have been designed to cover a wider field of application than is possible with the deflectional type. The standard instrument has a minimum scale span of 8 mV. and a maximum full scale balance speed of 8 seconds.

Although designed for industrial use, the new single or multipoint electronic recorder shown by the Cambridge Instrument Co., Ltd., is suitable for applications in research laboratories where accuracy, sensitivity, speed of response and great stability are required. It is of the continuously balancing type, the rebalancing of the measuring circuit being effected by means of a small servomotor. Unit construction of the amplifier and hinged mounting of the mechanism facilitate replacements and servicing.

An important feature of the new Cambridge infra-red pyrometer is that it is capable of measuring temperatures below 150° C.—much below the normal range of the ordinary radiation pyrometer. The intensity of radiation from a calibrated source incorporated in the instrument is compared by reference to an indicator unit with the unknown radiation input. A 6 volt battery provides current for the known source, and at the point of exact comparison this current is proportional to the tempera-



Hilger direct reading spectrograph

ture of the unknown source and deflects a self contained galvanometer calibrated in degrees of temperature.

Based on the design of C. R. Barber, the platinum resistance thermometer exhibited by H. Tinsley & Co., Ltd., consists of a strain-free platinum wire element contained in a twin-bore tube of special construction. Gold potential and current leads are used to minimise the lead resistance, and are insulated by a pair of twin-bore silica sheaths. The outer sheath is of a glass specially selected to meet the requirements of temperature and freedom from contaminants. The thermometer is helium-filled and hermetically sealed, and the temperature range is — 200° C. to 700° C.

Where it is desired to use a pneumatic instrument for indicating, recording, or controlling temperature, the thermoelectric pneumatic transducer shown by Elliott Brothers (London), Ltd., will convert the e.m.f. from a thermocouple into an output of 3–15 lb./sq. in. The instrument is also available for use with resistance thermometers.

Although not an instrument for temperature measurement and control, the Elliott CO_2 analyser is connected with furnaces, where it is used for accurately measuring the CO_2 content of flue gases. The fundamental measuring circuit consists of a current fed bridge, two arms of which are associated with the flue gas sample and the other two with the air reference. Change in the thermal conductivity of the flue gas due to the variation in the amount of carbon dioxide, cause an equivalent change in the resistance of the appropriate arms of the bridge circuit, a change which is measured by a moving coil instrument calibrated in terms of the percentage CO_2 content of the flue gases.

Analytical Equipment

An important item of analytical equipment was shown by Hilger & Watts, Ltd. It was a direct reading attachment to the Medium Quartz Spectrograph, E750, a combination forming a direct reading spectrometer which is less costly than those hitherto available. It is suitable for analyses of up to 11 elements in most non-ferrous alloys, and has also been used with success for the estimation of additives in oil (calcium, barium, phosphorus and zinc); also for phosphorus in steel.

Tinsley Polarograph Minor

The attachment replaces the plateholder of the spectrograph, and it contains slits in the focal plane to isolate the spectral rays required, with individual mirror systems to lead the rays on to individual multiplier cells. Leads connect the attachment to an electric console, and during analyses the individual multiplier currents are integrated on their condensers. The integration period can be controlled by time, or by the use of one element as a standard. At the conclusion of the integration the condenser potentials are measured one by one, at intervals of five seconds. The results are displayed on a meter, and a jack-point is also provided to allow a pen-recorder to be attached.

The Tinsley recording polarograph featured on the stand of Evershed & Vignoles, Ltd., comprises a polarograph, D.C. amplifier and recorder mounted together in a hardwood case. The polarising voltage is derived from an auto-potentiometer driven by a synchronous motor. The battery voltage for the potentiometer can readily be standardised against a Weston cell. Ranges covered are 0·1 μA to 150 μA in 34 steps, and a counter current circuit is included, controlled by a 10 step switch, the value automatically increasing on the high sensitivities. To give clearer definition of substances close together on the potential scale, a derivative circuit is included.

The Tinsley Polarograph Minor, also shown on this stand, is a small non-recording instrument which operates from A.C. mains in conjunction with internal batteries. Sixteen ranges are available, with a maximum sensitivity of 0·02 micro-amp. for full scale deflection. Changes in current of 100 micro-micro-amp. may be detected. The polarising potentiometer has a 3-position drive, and can be motor-driven free, or step-by-step in 50 mV. divisions. A selector switch is provided for amperometric and certain potentiometric titrations.

The analytical equipment shown by J. W. Towers & Co., Ltd., included electrolytic analysis apparatus consisting of a magnetic stirrer and hotplate fitted with suitable electrode holders. The use of magnetic stirring

Beck No. 50 Universal microscope

enables very efficient agitation to be obtained, and the speed of operation is accelerated; for example, 1g. of copper can be deposited in 20 minutes, compared with 30 minutes taken with conventional apparatus. This type of equipment is also constructed in the form of multi-test units.

The Towers potentiometric titration apparatus is a compact unit for carrying out acid-base and redox titrations easily and rapidly. It consists of a combined magnetic stirrer and hotplate, to which is fitted a stainless steel tube as support for a Towers double burette holder and an electrode holder of plastic and stainless steel. The apparatus may be used with a wide variety of potentiometers, and also direct with μH meters.

A method has been developed by B.I.S.R.A. for the mercury cathode electrolysis of steel solutions. The specified conditions are applicable over a wide range of alloy compositions, and tests have shown that the residual electrolyte quantitatively contains and can be used for the determination of elements such as aluminium, titanium, vanadium and zirconium. The conditions are designed to permit the optimum removal rate of cathodically deposited elements, e.g. iron, chromium, nickel, on a large weight basis, thus providing a solution suitable for the determination of residual trace constituents, e.g. aluminium or titanium $<0{\cdot}01\%$. Suitable apparatus was shown by Baird & Tatlock (London), Ltd., and Griffin & George, Ltd.

Vacuum Equipment

The range of gas ballasted rotary pumps shown by Edwards High Vacuum, Ltd., have the ability to handle contaminating vapours at relatively high intake pressure without contamination of the oil. They may be used, according to pressure requirements, in operation with high speed vapour pump combinations, on their own, or in combination with a condenser. One of the latter units shown was capable of handling 10 lb. of water vapour per hour, and a demonstration illustrated the ability of the gas ballasted rotary pump to pump methylated spirit vapour without contamination of the pump oil.

Also shown on the Edwards' stand were two examples of high speed vapour pump combinations, these giving high pumping speeds throughout the wide pressure range of 1 to 10^{-5} mm. Hg with backing pressures as high as 2–3 mm. Hg. They were: a 1604–16 in. diameter four-stage vapour pump complete with valve, backed by a 9B3 three-stage vapour booster pump; and a 902—9 in. diameter two-stage vapour pump complete with valve, backed by a 9B1 single-stage vapour booster pump.

On the vacuum metallurgy side, the Edwards' display included a high vacuum melting and casting furnace and an experimental vacuum arc furnace. The former is a $\frac{1}{2}$ lb. capacity resistance heated furnace made suitable for sintering, melting and casting in a high vacuum with a temperature limit in excess of 2,000° C. Provision is made for working in different atmospheres and suitable controls and sight glasses are provided to allow full supervision of the melt. The furnace is detachable from a mobile pumping unit consisting of a 403 vapour pump with a 7L4 baffle-valve and 1S150 rotary backing pump.

The laboratory arc furnace permits the melting and coating of refractory metals and alloys at temperatures up to and above 4,000° C. The furnace is suitable for use with both consumable and non-consumable electrodes and employs a water-cooled hearth or crucible. Adequate pumping capacity for the use of the vacuum-arc in exploratory work is provided by a 9B3 booster pump.

Originally exhibited in 1953, a new version was shown of the equipment for detecting at a reduced pressure dissolved gases in aluminium alloys. The apparatus has been designed as a commercial unit in co-operation with the B.N.F.M.R.A. Tests may be carried out simply and

Hilger surface finish microscope

quickly by semi-skilled operators on the foundry floor before casting, to determine whether further degassing treatment is necessary.

A sputtering unit shown is fitted with a water-cooled cathode 18½ in. diameter and is suitable for both conventional sputtering and the new technique of reactive sputtering in a controlled oxygen atmosphere in order to deposit conducting metal oxide films. Precise methods of gas mixing have been devised and very much higher sputtering rates are made possible by a 6 kW. high-tension power supply. A maximum current density of 1·2 mA/sq. cm. at an applied voltage of 3V. is now available and, for example, cadmium oxide film with a resistance of 100 ohms per square and an optical transmission of 50% can be deposited on glass in five minutes.

Microscopy

The No. 50 Universal microscope exhibited by R. & J. Beck, Ltd., has been designed to meet the need for the research worker to have available equipment for carrying out the latest advances in high power microscopic techniques, and to do so in a manner which enables the operator to achieve the highest standard of performance, coupled with convenience of manipulation. Provision is made for both transparent and incident illumination by light-field, dark-field, phase contrast and polarised light methods. Because the requirements are so specialised, macroscopic work at magnifying powers below 12 is not catered for in this instrument. The latest design incorporates a number of modifications found to be desirable by experience. They include : circular revolving stage with mechanical traversing motions, calibrated with scales and verniers ; a speeded shutter fitted to the camera head, giving a choice of eight exposure speeds with T and B settings ; and removable camera bellows enabling a 35 mm. film camera to be employed in place of the customary ¼-plate reflex head.

In many branches of industry it is necessary to examine surface finish to very fine limits. Piston rings, ball bearings, ball races, injection moulds, etc., should have a finish good to a few millionths of an inch. This goes beyond the resolving power of the optical microscope, and these ultra-fine finishes can only be examined by using interference techniques. Hilger & Watts, Ltd., have now produced a surface finish microscope, based on these methods, which is suitable for use by the mechanic either on the bench or, by using the special V-base, directly on the machine without dismantling the work. The magnification is × 125, which is sufficient for workshop use. For record purposes a camera attachment is available. This is designed to take single exposures on 35 mm. film at a magnification of × 30. With a fine grain emulsion film the definition of the multiple-beam fringes is good enough to allow of enlargement to three or four times the original size. In this way it is possible to provide a mechanic with illustrations of the surface finish with which he can compare his work during the finishing operations.

On the stand of Nash & Thompson, Ltd., equipment designed for the electrolytic polishing of specimens destined for metallographic examinations was shown. This apparatus has been available in two forms. In one the electrode and stirrer assembly is mounted on the main control cabinet, and in the second this is a separate free-standing assembly. Polishing currents up to 5 amp. at 70 volt are available from the instrument, and both ammeter and voltmeter are in circuit all the time, thus allowing complete supervision of the polishing process. The instrument accepts a standard 1,000 ml. beaker to contain the electrolyte, and a range of accessories, including a glass cooling coil, glass stirrers and a variety of cathodes is available. In future the cabinet version will no longer be manufactured, attention being concentrated on an improved version of the free-standing head polisher.

New Engineering Workshops for British Oxygen

A LARGE extension for plant manufacture is now being built by the British Oxygen Engineering Company at Edmonton. The new plant department workshops have become necessary as a result of the continuous increase in the sales of plant and equipment for use both in this country and overseas. The new building will be completed by next January and will be occupied in April. A rapid construction programme has been made possible by the adoption of building and construction methods already standardised by the Company. The building has been designed by B.O.E.'s own staff of architects and civil engineers, who are also supervising its construction.

Completion of the new plant buildings will complete a programme started in 1954 to centralise the British Oxygen Company's engineering and plant manufacturing activities at Edmonton. When the workshops are completed, it will be possible to relieve congestion in the existing plant shops, which will then be used for the fabrication of small air separation units, and will also provide a much-needed extension to the compressor, pump and expansion engine assembly shops. In addition to the new plant buildings, an extension to the existing evaporator shop has already been completed. This shop is reserved for the manufacture and assembly of distribution and control equipment normally installed in the works of the Company's customers.

These new buildings will not only provide adequate space for quantity production of the British Oxygen Engineering Company's standard and established plant and equipment, but will also provide ample accommodation for their large programme for the development of equipment of new design and processes exploiting novel circuits.

Kent Long Service

AN unusual number of long-service certificates was presented by Commander P. W. Kent, R.N., Chairman of George Kent, Ltd., at the annual ceremony at the Luton Works on November 18th. Four members received the award for 50 years' service and 28 the certificate marking the completion of 25 years. The award for 50 years consists, traditionally, in an endorsement on the long-service certificate with a cheque for £25.

Change of Address

THE Sheffield office of Head Wrightson & Co., Ltd. is now at 46, Rutland Park, Sheffield, 10.

Ninth B.I.S.R.A. Chemists' Conference

The Ninth B.I.S.R.A. Chemists' Conference was held recently at Swanwick in Derbyshire. In this account, reference is made to papers on the analysis of silicon iron, the gravimetric determination of sulphur, and the absorptiometric determination of copper.

THE Metallurgy Division of the British Iron and Steel Research Association held the ninth of its series of chemists' conferences at Swanwick in Derbyshire on October 11th and 12th. As in previous years, two of the sessions were devoted to analytical techniques, and the third to a topic linking the chemist and the steelmaker. The subjects and speakers were as follows :

The Determination of Nitrogen in Iron and Steel, presented by H. A. SLOMAN (National Physical Laboratory).

The Analysis of Silicon Iron, presented by R. H. A. CRAWLEY (British Thomson-Houston Co., Ltd.).

The Gravimetric Determination of Sulphur, presented by B. BAGSHAWE (Brown-Firth Research Laboratories).

The Absorptiometric Determination of Copper, presented by L. E. GARDNER (Edgar Allen & Co., Ltd.).

Some Experiences with the A.R.L. Quantometer, presented by W. S. SYKES (Steel, Peech & Tozer).

In the following account reference is made to the middle three papers in this list.

Ill-health again prevented DR. E. GREGORY from being present, and the chair was once more taken by MR. B. BAGSHAWE. Introducing the conference, the Chairman reviewed the work carried out by the Methods of Analysis Committee of B.I.S.R.A. during the past year. Since the last conference, five papers have been published (one of them in METALLURGIA) and five new parts have been added to British Standard 1121 : METHODS FOR THE ANALYSIS OF IRON AND STEEL : Part 32 for the absorptiometric determination of tungsten ; Part 33 for iron in ores, slags and refractories ; Part 34 for molybdenum ; Part 35 for aluminium ; and B.S. 1121C for mercury cathode electrolysis. These bring the total of new parts added to B.S. 1121 since 1945 to 32 ; most of them were the work of the Methods of Analysis Committee. Mr. Bagshawe then went on to review briefly the work now in progress : the determination of alumina in raw materials and slags ; a survey of methods for determining phosphorus in all classes of steel ; an extensive programme in connection with the low-alloy steel and mild steel residual series of spectrographic standards ; investigations into methods for determining vanadium in all steels (shortly to be published) ; work on the revision of B.S. 1121, Part 1, for sulphur ; methods for the spectrographic analysis of residual elements in steel ; the development of solution methods for spectrographic analysis ; and research on physico-chemical methods for the determination of boron and lead.

Analysis of Silicon Iron

Three papers were presented and discussed in the second session of the conference. The first of these, by MR. R. H. A. CRAWLEY of the British Thomson-Houston Co., Ltd., was on the analysis of silicon iron. Certain trace impurities have important effects on the electrical and magnetic properties of silicon iron, and there is therefore a need for methods of analysis suitable for estimating accurately amounts of as little as 0·01% and less of these impurities.

The Electric Sheet Analysis Sub-Committee was formed to investigate methods for the analysis of carbon, nitrogen, sulphur, phosphorus, aluminium, arsenic, and titanium. (Arsenic was studied because of its possible effect on the determination of phosphorus ; titanium because the presence of its nitride had been reported in silicon iron). This programme of work was largely carried out co-operatively by the members of the Sub-Committee.

Impurities can be classified in two groups according to their effects :—

(*i*) impurities which affect the magnetic properties of the steel ;

(*ii*) impurities which affect the orientation of the crystals in sheet.

Of impurities affecting the magnetic properties, carbon is the most important. Its presence increases the hysteresis loss and reduces the magnetic permeability of the metal. Oxygen and sulphur are similarly deleterious, though less so. Oxygen and nitrogen are believed to be the cause of ageing (increase of core loss with time) ; nitrogen also inhibits grain growth and reduces the maximum permeability. In small quantities, phosphorus appears to have a beneficial effect, perhaps because of its chemical affinity for oxygen. Like silicon, aluminium appears to improve the magnetic properties, but unlike silicon it does not lower the ductility of the metal.

Among impurities which inhibit the formation of properly-orientated crystals, carbon again takes first place ; nitrogen, too, is very harmful in this respect. Although aluminium itself has little effect, aluminium oxide is deleterious.

Conventional methods for the determination of carbon in steel are not suitable for silicon iron, which contains 0·04% carbon or less. The Sub-Committee examined several methods :

(*i*) the Wells method, in which a refined version of the orthodox combustion technique is combined with a low-pressure system for increasing the evolved carbon dioxide ;

(*ii*) the Yensen method, using a low-pressure combustion apparatus in which the carbon dioxide is collected in a manner similar to that used in the Wells method ; and

(*iii*) "large weight" methods, in which carbon is separated as carbide by dissolving the sample in acid potassium copper chloride.

The results obtained by these various methods are show in Table I.

TABLE I.—RESULTS OBTAINED BY VARIOUS METHODS FOR THE DETERMINATION OF CARBON IN ELECTRICAL SHEET.

Analyst	Method	Sample MGS/200 % C	Sample MGS/201 % C	Sample MGS/202 % C
1	Acid copper potassium chloride.	0·0044	0·0065	0·045
2	Yensen	0·0037	0·0043	0·038
3	Combustion—volumetric	0·006	0·007	0·045
4	Acid copper potassium chloride	0·009	0·0052	0·048
	Wells	0·0046	0·0045	0·045
5	Wells	0·0046	0·0047	0·045
6	Yensen	0·0043	0·0043	0·043
7	Wells	0·0048	0·0045	0·045

The members of the Sub-Committee who used " large-weight " methods were not fully satisfied with the results they obtained, which were not always reproducible, and the Wells and the Yensen methods are therefore recommended in preference. There was some controversy even about the results obtained by the Wells and the Yensen methods; errors were traced to variations between coarse and fine millings and the method of drying them. Samples in the form of chippings or punchings are therefore preferable.

The determination of nitrogen in silicon iron is of great importance. In determining such very small quantities (less than 0·005%), it is essential to keep the blank as small as possible; high and inaccurate blanks were the cause of many of the discrepancies encountered in the Sub-Committee's earlier work. Various means of reducing blanks were investigated: (*i*) de-ionising the water used by passing it through a cation exchange resin (not a mixed bed resin, which will introduce nitrogen); (*ii*) re-distilling the sulphuric acid to eliminate ammonia and some other nitrogenous compounds; and (*iii*) working in a special laboratory from which ammonia was excluded.

The most satisfactory means of preparing the solution for analysis was found to be to treat the sample with dilute acid and then to separate the insoluble residue in a centrifuge and fume it with sulphuric acid.

Most members of the Sub-Committee preferred to liberate ammonia by steam distillation of a solution containing caustic alkali. Where more than 0·01% nitrogen is present, a volumetric finish is satisfactory, but where the amount of nitrogen is less than 0·01% a colorimetric finish with Nessler's reagent is more sensitive. Still more sensitive is the pyridine/pyrazol reagent proposed by Kruse and Mellon, but stringent precautions are needed to reduce the blank when it is used.

For determining sulphur, the combustion method is simple and can be recommended, but an occasional check by the barium sulphate gravimetric method is desirable. The method given in B.S. 1121 : Part 9 is recommended for referee analysis for phosphorus.

The Sub-Committee has examined two methods for the determination of aluminium: the colorimetric method using aurine tricarboxylic acid, and a gravimetric method (in which aluminium is precipitated as quinolate after the sample has been dissolved in hydrochloric acid, oxidised, and iron extracted with amyl acetate). The gravimetric method is less satisfactory for residual amounts of aluminium, but is suitable for amounts of 0·05% and over.

For determining arsenic, a colorimetric method was found to be both accurate and sensitive, as well as more rapid than the volumetric procedure. The colorimetric method requires only a small sample, and interference by silicon is thus reduced. A solution of the sample in sulphuric acid is reduced with a mixture of potassium bromide and hydrazine sulphate. Arsenic is then distilled as chloride, collected in water, and oxidised to arsenate before being determined as arseno-molybdate with hydrazine sulphate.

The determination of titanium was undertaken because of the possible presence of titanium nitride in silicon steel. Colorimetric methods have been favoured for the determination of titanium, but although satisfactory results are obtained for total titanium, they do not give an accurate measure of the ratio of soluble to insoluble titanium. An absorptiometric procedure has been developed which is more sensitive than the standard colorimetric method and requires only a 1-g. sample. In this modified procedure, zirconium is added after silica and the carbides have been filtered off from the solution in hydrochloric acid, and titanium is co-precipitated with it as the hydroxyphenyl arsenic acid complex. After ignition, fusion, and extraction, the precipitate is determined as a complex with 1 : 2 dihydroxy-benzene 3 : 5 disulphonic acid. Titanium in the silica residue is similarly determined after the silica has been volatilised as fluoride.

Discussion

In the ensuing discussion one speaker expressed the opinion that the method described for determining titanium was unnecessarily lengthy, and suggested that it would be better to precipitate all the titanium and some of the iron with cupferron reagent, as in the procedure used by the American Society for Testing Metals. Mr. Crawley replied that the objections to this are two-fold: (*a*) a great deal of cupferron is required if all the titanium is to be precipitated; (*b*) it is necessary to filter off the silica.

Mr. Crawley agreed with the same speaker's view that combustion methods do not tend to give lower results than others if the combustion apparatus is used correctly. He assured another speaker about the reproducibility and colour stability of the modified method for determining arsenic.

Gravimetric Determination of Sulphur

Mr. B. Bagshawe vacated the chair for a short period to present a paper on the gravimetric determination of sulphur. He began by referring to the historical associations between this subject and the development of chemical analysis in the steel industry. The problem of determining sulphur was considered by the Standard Methods of Analysis Sub-Committee, set up in 1939 after representations had been made to the British Standards Institution by a committee of representatives of steel-makers under the chairmanship of Sir William Larke K.B.E. Strong views had then been expressed about the reliability of existing methods of analysis.

The Sub-Committee carried out extensive collaborative tests and in its first report, published in 1942, the *aqua-regia*/barium-sulphate gravimetric method was recommended for the analysis of sulphur in steels. This report was subsequently accepted by the British Standards Institution and the barium sulphate method was published as B.S. 1121 : Part 1 A : 1943.

Recently, the British Standards Institution has asked for this method to be revised and its scope extended to include alloy steels. A series of test analyses was accordingly arranged with samples to which chromium had been added in known amounts. The results of some of the analyses were low; others failed altogether. The main factor affecting the analyses has been found to be the co-precipitation of sulphur in basic chromium compounds formed during the baking treatment which is used for removing residual nitrates from the precipitate. With chromium steels, the margin of temperature is very narrow. The British Standard specifies a baking temperature of 300° C.; but it has since been found that even 250° C. is too high for chromium steels.

To prevent the formation of basic chromium compounds, perchloric acid was added; this, although satisfactory for plain carbon steels, gave low results for

chromium steels. Organic reducing agents were next investigated, and it was found that if A.R. hydroxylamine hydrochloride was used to decompose residual nitrate, the critical baking treatment could be dispensed with entirely, and the method became applicable to all chromium steels.

Mr. Bagshawe quoted results obtained with a series of synthetic samples containing up to 20% chromium ; these showed that this simplified method is consistent and accurate to within 0·002% sulphur. There is nothing to suggest that the method would not be equally applicable to samples containing more than 20% chromium. Low results have been obtained with titanium steels, but with this exception the method is suitable for all classes of highly-alloyed steels. It is therefore to be recommended to the British Standards Institution to replace the barium sulphate procedure given in B.S. 1121 : Part 1A.

Discussion

In the discussion on this paper, Mr. Bagshawe was asked about the relative times required for the new and the old method. He pointed out that eliminating the baking treatment saves 30 minutes ; there is also a further saving of time because no additional evaporation is required. Answering subsequent questions, Mr. Bagshawe gave some additional information about the new method. By eliminating the baking treatment there would appear to be a risk of contamination of the residue by silicon ; but tests with a 4% silicon steel have given results agreeing to within ± 0·001% with the values obtained by the combustion method, and only insignificant amounts of silicon could be detected in the precipitate. An extremely wide range of complex steels has been investigated, including tungsten steels.

Absorptiometric Determination of Copper

Mr. L. E. Gardner of Edgar Allen and Company, Ltd., next read a paper on the absorptiometric determination of copper in which three colorimetric procedures were described : (*i*) the direct diethyldithiocarbamate method; (*ii*) the extraction diethyldithiocarbamate method ; and (*iii*) the 2–2′ diquinolyl method.

(*i*) *The Direct Diethyldithiocarbamate Method.*

Sodium diethydithiocarbamate is added to an aliquot portion in ammoniacal solution in the presence of gum acacia. Metals insoluble in aqueous ammonia are held in solution by ammonium citrate ; interference from nickel is suppressed by adding excess ammonium hydroxide. The colour produced is measured on an absorptiometer. The tests carried out by the Sub-Committee indicated that the presence of cobalt or of large quantities of manganese influenced the results obtained, and it was felt that the direct method was not of sufficiently general application for referee purposes.

(*ii*) *The Extraction Diethyldithiocarbamate Method.*

Disodium ethylenediamine tetra-acetate is used to prevent interference ; the coloured complex is extracted with an organic solvent (butyl acetate or carbon tetrachloride). With carbon tetrachloride, it was found difficult to extract the copper complex completely ; butyl acetate was better, but less convenient. As interference by cobalt and nickel, although much less than in the direct method, was still not eliminated, the Sub-Committee turned its attention to the 2–2′ diquinolyl method.

(*iii*) *The 2–2′ Diquinolyl Method.*

The technique with this reagent is simple : the sample is dissoved in a phosphoric-sulphuric acid mixture, copper is reduced to the cuprous state with hydroxylamine hydrochloride, buffered with ammoniacal citrate solution, and then a solution of the diquinolyl reagent in amyl alcohol is added. The alcohol is separated, carrying the purple copper complex in solution, and the colorimetric measurement is made.

After comprehensive tests, this procedure has been recommended for steels containing up to 2% copper. (Volumetric or other methods are recommended for referee analysis of steels containing more than 2% of copper). It is important that the reagent should be pure, and that too much time should not elapse between adding the hydroxylamine, adding the diquinolyl reagent, and taking the reading on the colorimeter.

The method is an ideal one for alloy steels. The only element that interferes is tungsten, the effects of which can be eliminated by adding more phosphoric acid.

The results obtained in the tests were very satisfactory and agreed well with previous chemical determinations. The diquinolyl reagent is sensitive to one part of copper in one hundred million. The method is to be submitted to the British Standards Institution for adoption as a British Standard.

In the third session, Mr. W. S. Sykes of Steel, Peech and Tozer, spoke on some experiences with the A.R.L. Quantometer, which has recently been described in Metallurgia.

New Rolling Mill for Australia

Davy and United Engineering Co., Ltd., have received an order worth some £550,000 to build a new 18 in. Morgan continuous skelp and strip mill for the steelworks at Newcastle, New South Wales, of Broken Hill Proprietary Co., Ltd. This mill will primarily be engaged on quantity production of high quality steel strip for subsequent processing into tubes—strip for this purpose is known in the trade as skelp—and medium width strip for a variety of other applications. A mill of this size and type can produce in excess of half-a-million tons of strip a year, and its installation is another indication of the steady expansion programme being pursued by Australia's own steel industry. The Broken Hill mill will consist of fourteen stands, and will be supplied with a considerable amount of auxiliary handling and control equipment. Delivery is expected to be made in early 1957.

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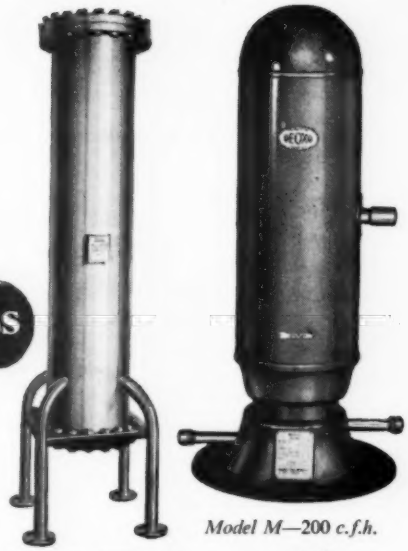

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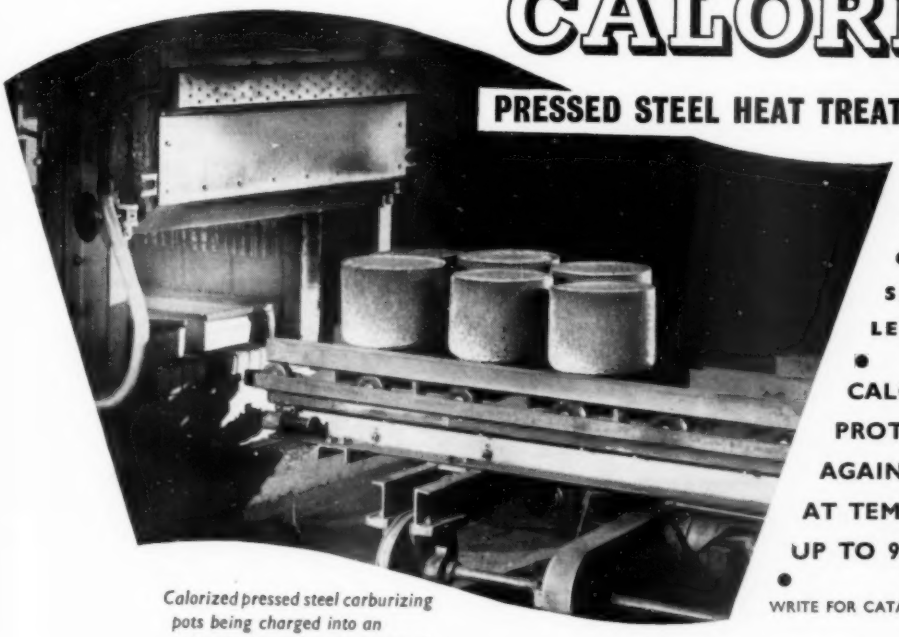

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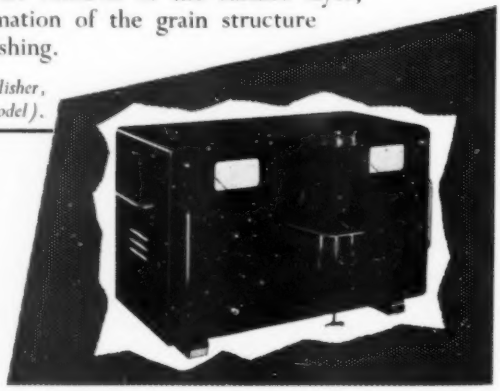

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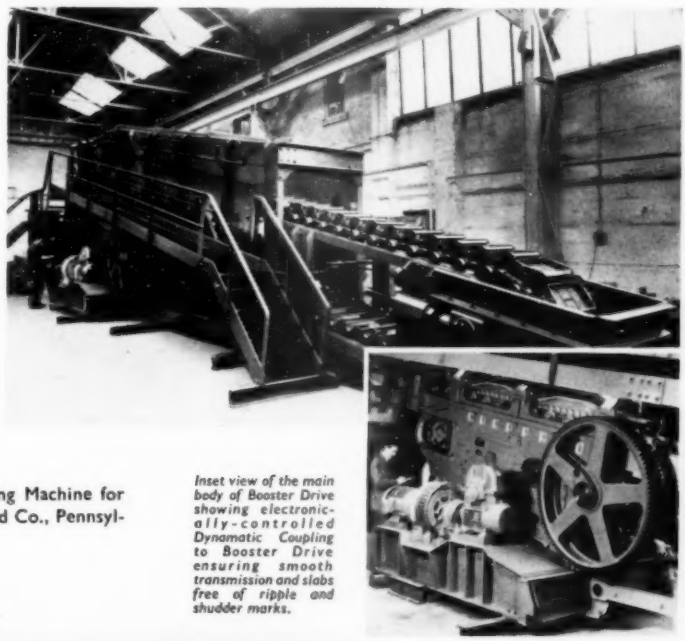

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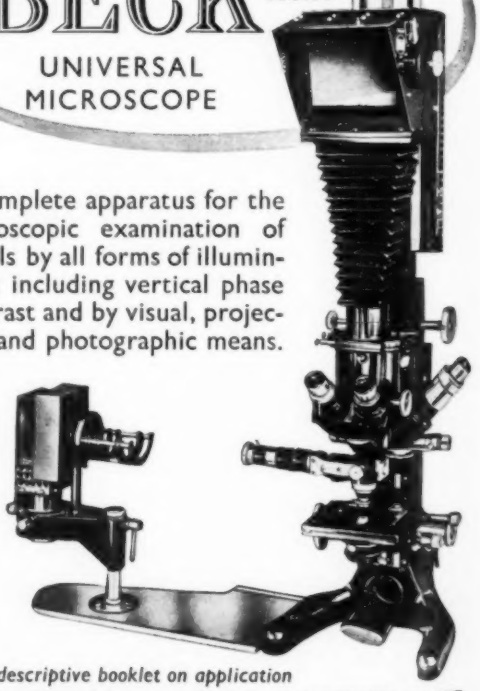

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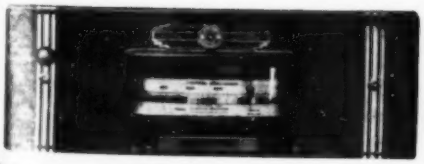

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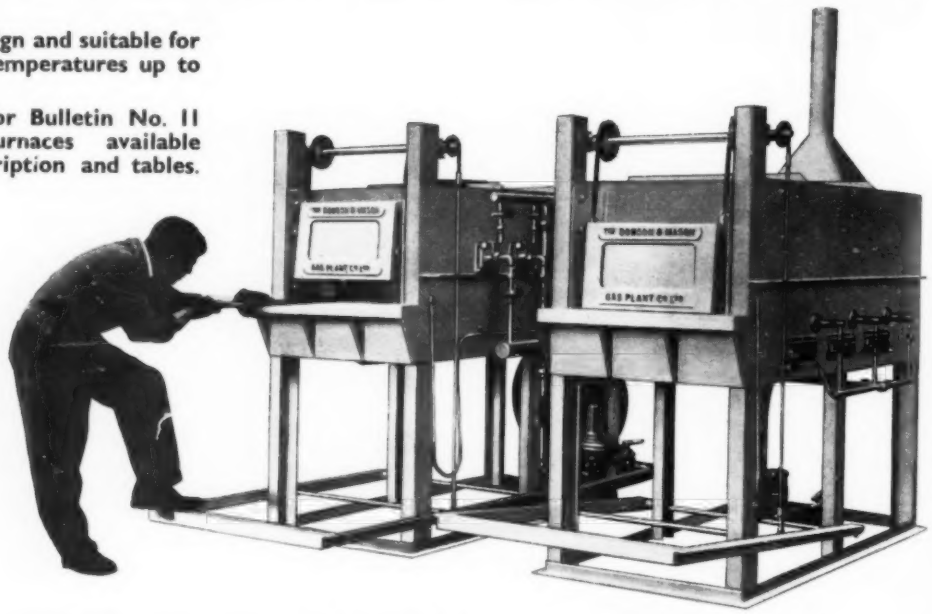

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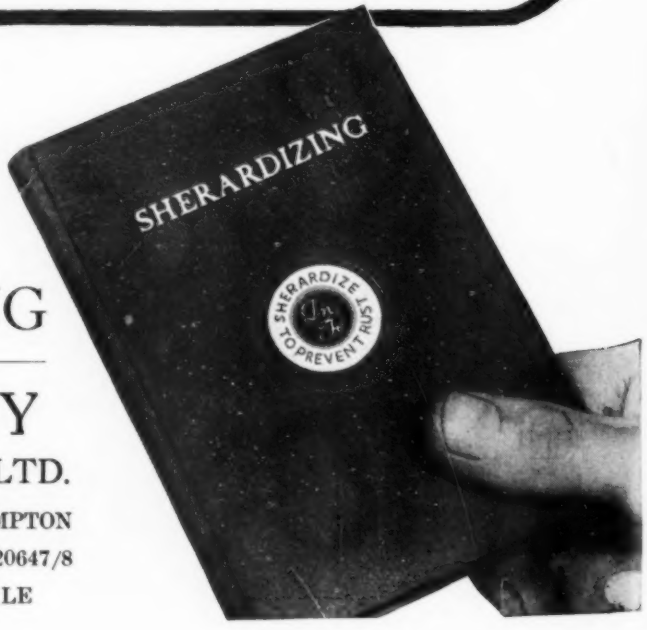

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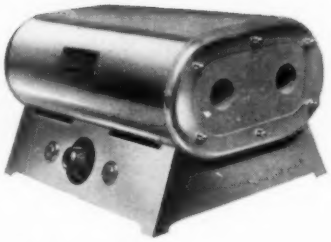

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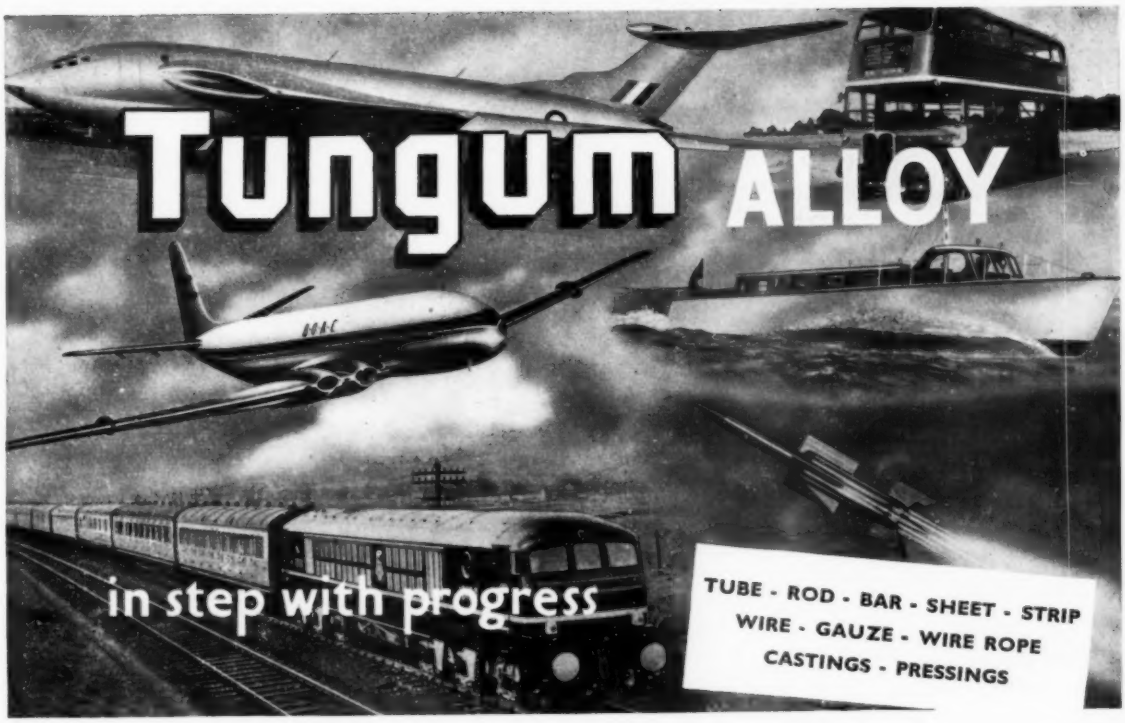

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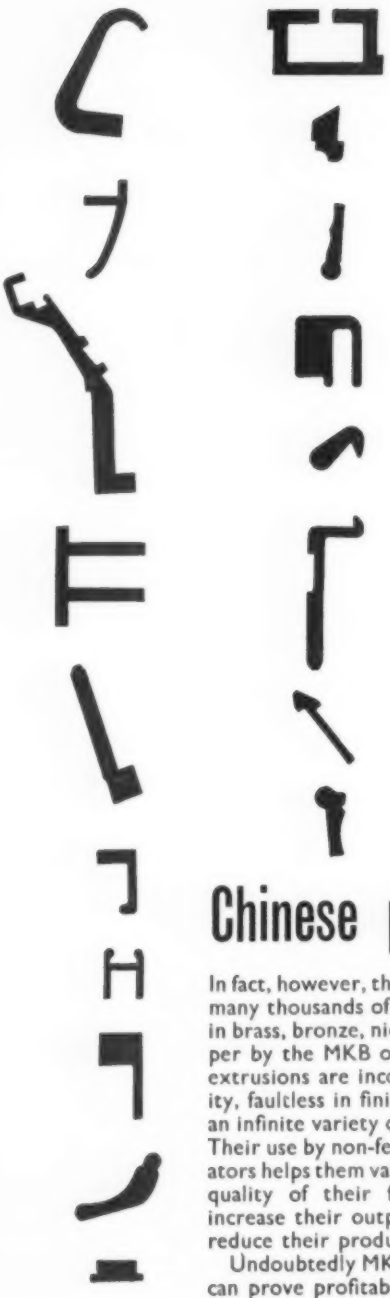

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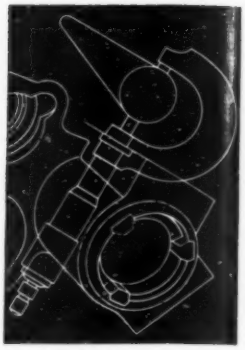

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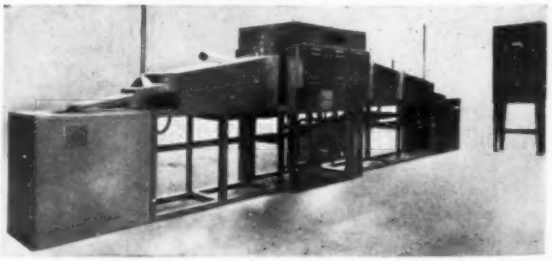

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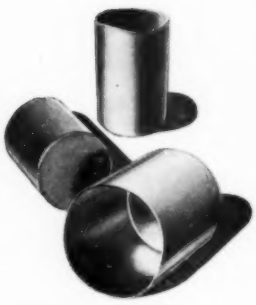

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Classified Advertisements are inserted at the rate of 2/6 per line.

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The engagement of persons answering these advertisements must be made through a local office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18–64 inclusive or a woman 18–59 inclusive unless he or she, or the employment is excepted from the provisions of the Notification of Vacancies Order, 1952.

MAINTENANCE ENGINEER, age 30/35, with A.M.I.Chem.E., A.M.I. Mech.E., or similar qualification, required for large Chemical Works in Lancashire. Good Salary and prospects for the right man. Pension Scheme.

Apply in writing, giving full details of education, qualifications and experience to :—McKechnie Brothers Ltd., P.O. Box No. 4, Widnes, Lancs.

THE ENGLISH ELECTRIC COMPANY LIMITED

at Stafford

require an

ASSISTANT CHEMIST

having some experience of metallurgical analysis and/or electroplating solution analysis.

Preference will be given to young men who have completed National Service.

The appointment is permanent, progressive and pensionable. Please write giving full details of qualifications and experience and quoting Ref. 1358C. to Dept. C.P.S., 336/7 Strand, W.C.2.

RESEARCH ASSISTANTS—B.W.R.A. laboratories at Abington (Cambs.) and Park Crescent have vacancies for research assistants as members of research teams on the welding of ferrous and non-ferrous metals. Salaries within the range £400–£600 per annum. Appointments as junior assistants would also be considered for suitable applicants. Apply—Secretary, 29 Park Crescent, London, W.1.

A PHYSICIST, METALLURGIST or CHEMIST is required by the Nelson Research Laboratories, English Electric Co. Ltd., Stafford.

for work involving the application of X-ray diffraction techniques to problems encountered in the fields of Metallurgy and Ceramic technology.

The post would be suitable for a recent graduate though applications from non-graduates with suitable experience in the above subjects will be considered.

Conditions for employment and salary are attractive. Please reply to Dept. C.P.S., 336/7 Strand, W.C.2. quoting Ref. No. 996A.

SITUATIONS VACANT—*continued*

GRADUATE INVESTIGATOR. An investigator is required by the British Welding Research Association for a new programme on the welding of copper and copper alloys. The appointment will be as Research Officer within the salary range £500–£800 per annum according to age and experience. The work will be carried on initially at Park Crescent but will be transferred to new metallurgical laboratories now being built at Abington (Cambs.). Apply—Secretary, 29 Park Crescent, London, W.1.

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Applicant must be in possession of Higher National Certificate in Mechanical or Electrical Engineering. If possible, he should have had five years' experience in light or medium engineering, and be conversant with modern mass-production methods.

He will be required to investigate fully new production methods and processes and will be required to work on his own with a minimum of supervision. Age 25 to 30.

THE MARKET RESEARCH DIVISION

requires applications from men with experience of sales analysis and forecasting, statistical analysis and investigations into marketing problems. Previous knowledge of motor vehicles would be a useful asset. Age 25 to 30.

Vacancies also exist in this Division for Clerks for work in connection with home and export analysis.

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Applications are invited for work in connection with mechanical testing of ferrous and non-ferrous materials. Age 23–35 years.

The above posts are permanent with good prospects. Salaries are dependent on qualifications and previous experience.

The Company operates Staff Pension and Life Assurance Schemes.

Five day week.

Applications, stating age, qualifications and previous experience to Personnel Manager.

ASSISTANT MANAGER wanted for large Copper Smelting Plant. Experience in the treatment of all grades of scrap and residues essential.

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SITUATIONS VACANT—*continued*

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McKECHNIE BROTHERS LTD., require an experienced Metallurgical Chemist for their Widnes Works. A.R.I.C. standard essential. Age 30/40.

Write, giving full details of experience and qualifications, to McKechnie Brothers, Ltd., P.O. Box 4, Widnes, Lancs.

BRITISH ALUMINIUM COMPANY require a Metallurgical Graduate preferably with some industrial or research experience, age 25–30, to assist the Senior Metallurgist at the Company's Head Office (London S.W.) in control of the quality of products and development of metallurgical processes at the Company's factories. Salary according to qualifications, age and experience. Write to Box M.104, L.P.E., 55 St. Martin's Lane, London, W.C.2.

QUASI-ARC LTD., Bilston, Staffs., has a vacancy for a Physical Metallurgist in its Welding Research Department. Candidates should have a degree or equivalent qualification in Metallurgy. Some experience in Metallography or Crystallography would be an advantage but is not essential. Five-day week. Pension Fund. Apply in writing to the Company, quoting reference M1.

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Applicants should have a degree in metallurgy or equivalent qualifications and should have some specialist knowledge of non-ferrous metallurgy including welding techniques.

Applicants should write in confidence giving full details of previous experience and training, mentioning, Ref. 1367D to Dept. C.P.S. 336/7 Strand, W.C.2.

CLASSIFIED ADVERTISEMENTS

SITUATIONS VACANT—*continued*

THE BRITISH THOMSON-HOUSTON Co., Ltd., has vacancies in its research laboratory at Rugby for qualified metallurgists and physicists for research on the properties and development of new alloys for nuclear reactors. There are openings for graduates with research experience and for men with Higher National Certificate. Application should be made to the Director of Research, British Thomson-Houston Co., Ltd., Rugby, stating age, qualifications and experience, and quoting reference CE.

METALLURGIST required to take charge of Metallurgical Laboratory serving a large light electrical engineering factory in West London. Work includes pressure diecasting and heat treatment of tool steel. A.I.M. or Degree in Metallurgy essential. Age 28 to 35. Salary up to £800 per annum. Apply stating age, education and experience to Box No. MY 13, METALLURGIA, 31 King Street West, Manchester, 3.

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G.K.N. Group Research Laboratory requires a Metallurgist to carry out work in the field of Titanium and its alloys. Candidate must have 1st or 2nd Class Honours Degree in Metallurgy and at least 2 years post graduate experience. Applications, in writing, giving full details, should be made to the Director of Research, G.K.N. Group Research Laboratory, Birmingham New Road, Lanesfield, Wolverhampton.

SITUATIONS VACANT—*continued*

THE Guest Keen and Nettlefolds Group Research Laboratory has an opening for qualified men to be engaged on technical liaison work between the laboratory and production units in the Group. An important part of the duties will be those of technical secretaries, and in addition to a degree or equivalent qualification, preferably in Engineering or Metallurgy, applicants should have some experience of work in industry and be competent to convey information by both the written and the spoken word. Applicants should be between 25 and 35 years of age and should write, giving full details of experience, to The Director of Research, G.K.N. Group Research Laboratory, Birmingham New Road, Lanesfield, Wolverhampton.

A SCIENTIFIC Research Officer required in new expanding laboratory for group investigating physical and mechanical properties of metals and other solids under extreme temperatures and vacuum. Degree or similar qualification in Physics, Metallurgy, or Engineering desirable. Good prospects. Salary in the range £600–£1,000. Apply, stating full particulars to The Secretary, Tube Investments Research Laboratories, Hinxton Hall, Nr. Saffron Walden, Essex.

ASSISTANT Metallurgist required to act as second in command of the Physical Test Laboratory. Applicants should have completed National Service and be qualified to Inter. B.Sc., or Higher National standard. Some experience of Mechanical Testing of ferrous and non-ferrous materials preferred.

Written applications only, giving full details of qualifications and previous experience to The Personnel Officer, The de Havilland Engine Co., Ltd., Leavesden Aerodrome, Nr. Watford, Herts.

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Applications close in New Zealand and London on January 15th, 1956.

THE Research Laboratories of the British Aluminium Co. Ltd., require a metallurgist, chemist or physicist of degree standard, preferably aged between 25 and 35 to build up and ultimately lead a group concerned with advanced basic and applied research on problems associated with the casting of aluminium and its alloys. A sound theoretical background is essential and some experience of casting, not necessarily of aluminium, would be advantageous. The post offers scope to a man capable of independent activity in a wide field. Apply to the Director of Research, The British Aluminium Co., Ltd., Chalfont Park, Gerrards Cross, Bucks.

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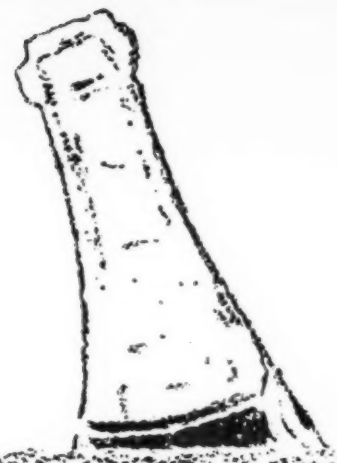
The Research Laboratories at Wembley are in pleasant surroundings yet convenient to the scientific and cultural amenities of London. The range of work and choice of subjects is wide. Scientific publication is encouraged.

The openings provide excellent opportunities for continuing contact with the academic schools of the country while working in association with a progressive manufacturing industry. Salaries offered will be commensurate with the expected standard of ability.

Anyone having the necessary high qualifications who is interested in exploring the opportunities presented by these appointments, is invited to apply to the Staff Manager (Ref. RLO/64), Research Laboratories, The General Electric Co. Ltd., East Lane, North Wembley, Mid'x.



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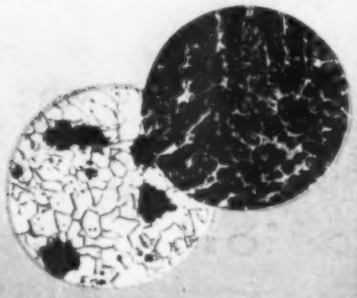
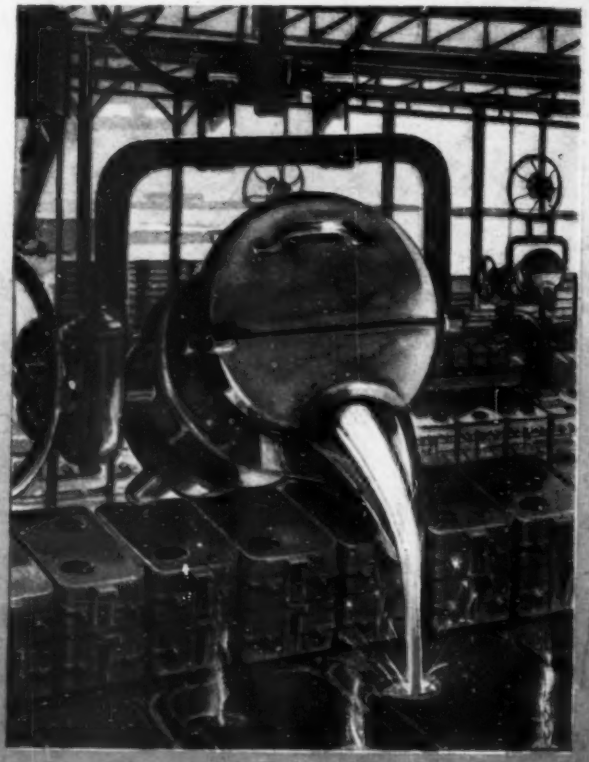
OF MANUFACTURE





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